Task 1 Technical Report
For
Mercury Removal in a Non-Thermal, Plasma-Based Multi-Pollutant Control Technology for Utility Boilers

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Abstract

This technical report describes the results from Task 1 of the Cooperative Agreement. Powerspan has installed, tested, and validated Hg SCEMS systems for measuring oxidized and elemental mercury at the pilot facility at R.E. Burger Generating Station in Shadyside, Ohio. When operating properly, these systems are capable of providing near real-time monitoring of inlet and outlet gas flow streams and are capable of extracting samples from different locations to characterize mercury removal at these different ECO process stages. This report discusses the final configuration of the Hg CEM systems and the operating protocols that increase the reliability of the HG SCEM measurements. Documentation on the testing done to verify the operating protocols is also provided. In addition the report provides details on the protocols developed and used for measurement of mercury in process liquid streams and in captured ash.

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1.0 Introduction

According to EPA's 1999 National Emissions Inventory, coal-fired electric power plants are the largest source of anthropogenic mercury air emissions in the United States. These power plants account for approximately 40% of total U.S. manmade mercury emissions. On December 15, 2003 the Environmental Protection Agency (EPA) proposed a rule to permanently cap and reduce mercury emissions from power plants. The EPA is proposing two alternatives for controlling emissions of mercury from utilities. The first proposed rule requires utilities to install controls known as “maximum achievable control technologies” (MACT) under section 112 of the Clean Air Act. If implemented, this proposal would reduce mercury emissions from U.S. coal-burning power plants nationwide by 14 tons (29 percent) by the end of 2007.

The second proposed rule establishes “standards of performance” limiting mercury emissions from new and existing utilities. This proposal, under section 111 of the Clean Air Act, would create a market based “cap-and trade” program that, if implemented, would reduce nationwide utility emissions of mercury in two distinct phases. In the first phase, due by 2010, emissions will be reduced by taking advantage of “co-benefit” controls - that is mercury reductions achieved by reducing SO_2, and NO_x emissions. When fully implemented, mercury emissions will be reduced by 33 tons (69 percent).

To implement a control strategy to meet mercury emission reductions requires the utility to understand the speciation of mercury in a flue gas stream. Gas phase mercury can be present in oxidized (Hg^+, Hg^{2+}), elemental (Hg^0), and particulate matter bound mercury forms. Oxidized and particulate mercury can be captured to varying degrees with conventional control technology, which is already available. These technologies include electrostatic precipitators (ESP’s), wet and dry flue gas desulfurization (FGD) scrubbers, NO_x control technologies, and fabric filters. [1] However, for utilities with high percentages of elemental mercury in their flue gas, the options for reducing emissions are limited and will rely on developing technologies including the ECO Process and activated carbon injection (ACI). Therefore, being able to measure mercury at low levels as well as speciate the mercury in flue gas streams is a requirement for any utility considering controls for mercury and for any technology company developing controls for coal-fired power plants.

Impinger based methods such as EPA Methods 29 and 101A have been successfully applied to determine total mercury, but do not speciate. More recently, a draft ASTM method commonly known as the Ontario Hydro method has been released. This method differentiates between elemental and oxidized forms of gas phase mercury and is useful for periodic testing. For semi-continuous monitoring, several types of Hg SCEMS instrumentation have been developed and are being tested. However, these methods are expensive to implement and require specially trained personnel to operate.

The Ontario-Hydro Method for mercury measurement has gained acceptance as a means to speciate mercury in a flue gas stream. This method uses an impinger train and wet chemistry to isolate separate fractions of mercury for analysis. The difficulties associated with this method are that (i) preparation and sample times are extensive, (ii) the results are not available immediately, (iii) typically an outside testing service is required to perform the testing due to the expertise and equipment required, (iv) the cost is substantial for each test event, and (v) it is difficult to measure at multiple sample points simultaneously. The Ontario-Hydro method has been setup for individual test events on a periodic basis and is useful for validating Hg SCEMS measurements due to its acceptance in the industry for making speciated Hg measurements.

One type of Hg SCEMS that has been developed for gas-phase Hg measurement is from PS Analytical (Kent, England). It uses wet chemistry to differentiate elemental mercury from oxidized mercury, and atomic fluorescence for mercury measurement. The system automates sampling, speciation, and mercury measurement to quantify the mercury in flue gas in near real time. Its use at a power plant on real flue gas requires protocols for validation and maintenance to insure reliable data collection. However, there are several factors to recognize before employing this type of instrumentation. They include: (i) the capital and operating cost of the equipment is high, (ii) operation requires specially trained personnel to closely monitor the equipment, (iii) operation requires the use of substantial amounts of high purity, caustic reagents and (iv) the complexity of the sampling process leads to frequent failures and time with the instrument out of service. However, when operating properly the instrument provides near real-time measurements of gas-phase Hg, as valuable tool for development and testing of mercury control technologies.

The overall objective of this project is to understand and maximize the mercury removal capability of the Electro-Catalytic Oxidation (ECO) process, while maintaining the removal capability of the technology for other pollutants including NO_x, SO_2, $PM_{2.5}$ and air toxic compounds. An integral part of the project is to be able to obtain consistent and reliable mercury measurements on a routine basis. Based on the benefits and problems of both measurement techniques, it was decided that a combination of Ontario-Hydro and Hg SCEMS measurements would be used to verify mercury removal and oxidation by the ECO process. The Hg SCEMS would be used to establish conditions and gain a detailed understanding of the process, while the Ontario-Hydro method would be used to validate the measurements being made by the Hg SCEMS instrumentation. Through investigation of the state of the art mercury monitoring systems and detailed discussions with US EPA personnel working with mercury measurement instrumentation, it was decided to purchase two of the recommended Hg SCEMS systems from PS Analytical for use at the ECO pilot.

Although the expectation was that the PS Analytical system was a proven technology ready for operation in power plant conditions, the effort required to obtain measurements with the Hg SCEMS instrumentation turned out to be extensive. It required substantial troubleshooting and modifications to get the instrumentation to a point where it could be used to acquire meaningful data. Unfortunately, the time required was a substantial amount of the schedule for this cooperative agreement. With all the effort, the Hg SCEMS equipment never reached a point where routine operation was possible. The instrumentation was capable of only limited operation with extensive oversight. This report focuses on the substantial efforts to develop operating procedures, protocols, troubleshooting, and modifications used to validate the Hg SCEMS instrumentation to be able to obtain reliable, speciated Hg measurements for this program.

In addition to gas-phase mercury measurements, techniques were developed to measure the mercury content of the ash captured by the pilot's dry electrostatic precipitator, the liquid streams internal to the ECO process, and the liquid co-product stream. The techniques developed were modifications of standard mercury analysis procedures which eliminated sample matrix effects unique to the ECO process fluids.

2.0 Executive Summary

Work under Task 1 of the Cooperative Agreement consisted of selecting, installing and validating instrumentation for the measurement of gas phase mercury at the ECO pilot installed at FirstEnergy's Burger Power Plant. After consultation with the US EPA and vendors, two Sir Galahad semi-continuous mercury emissions monitoring systems were purchased from PS Analytical. The mercury monitoring systems were designed to measure the elemental and oxidized mercury concentrations in flue gas and to operate continuously. Each system provided the capability of sampling from two locations. The purchased equipment included sample probes and sample conditioning systems for making speciated gas-phase mercury measurements. These features were considered essential for the planned parametric investigation of mercury removal in the ECO process.

Operation of the mercury SCEM required extensive experimentation and troubleshooting throughout the performance of this project. After exhaustive testing it was determined that the sampling system provided with the PS Analytical instruments was unable to perform adequately in the heavy ash environment that existed in pilot's inlet flue gas stream, drawn from the inlet of the Burger Plant's electrostatic precipitator. The reactive nature of the flue gas ash with mercury, combined with the inability to adequately clean the sample filter between sample events, skewed measurements of elemental and oxidized mercury. In addition, frequent sample contamination due to inadequate filtering of ash led to unreliable measurement of gas-phase mercury and required replacement of the inlet sample probe with an inertial separation probe from Apogee Scientific. The inertial separation probe improved measurement of elemental and oxidized mercury in the inlet flue gas. However, contamination with ash over time, and with boiler upset conditions, required frequent cleaning of the probe. The cleaning process became less effective at removing reactive ash with each cleaning event and probe replacement was eventually required. As a result of the problems encountered with speciated mercury measurement in the ash laden environment of pilot's inlet flue gas, a new duct configuration was installed for the pilot. The new ductwork provided flue gas from the outlet of the Burger Plant's Unit 4 electrostatic precipitator, reducing the ash loading on the pilot system by an order of magnitude, to levels expected for commercial ECO installations.

The probes supplied with the PS Analytical instrumentation were determined to perform well in the treated flue gas at the outlet of the ECO pilot. Removal of ash and fine aerosols by the ECO wet electrostatic precipitator eliminated the problems associated encountered with particulate matter in the inlet gas stream. The sample probes supplied with the instruments were used on the outlet gas throughout the testing performed for this project.

Problems associated with operation of sample conditioning equipment of the Hg SCEM systems required modifications to the conditioners and frequent replacement of failed or damaged components. Problems were encountered with sample gas flow, reagent flow, reagent chemistry and moisture removal. The complicated nature of the sample conditioning equipment required to make measurements of elemental and oxidized mercury in the gas phase necessitated constant operator attention. The systems were shutdown when that attention could not be provided due to manning limitations or unusual pilot plant operations.

When operating properly, the PS Analytical equipment provided agreement with measurements made using the Ontario-Hydro method of measuring mercury. Measurements made by Air Compliance Testing on the pilot's inlet and outlet flue gas streams demonstrated the ability of the PS Analytical instrumentation to obtain agreement with the accepted reference method for gas-phase mercury measurement.

The inability to make semi-continuous, gas-phase mercury measurement on a routine basis severely hampered the parametric investigation and optimization of the ECO process for mercury removal. While two complete measurement systems were purchased for this project, allowing for measurement at up to four locations, only a single system could routinely be kept in operation at any one time. The routine operation was limited to approximately 8 hours each day, when personnel dedicated to monitoring the instrumentation was available.

Measurement of mercury in the ECO process fluids was successfully accomplished throughout the project after modification of standard measurement methods. The modifications were required to eliminate effects of non-metallic compounds in the sample matrix of the ECO process streams.

3.0 ECO Pilot Overview

The ECO (Electro-catalytic Oxidation) system is a multi-pollutant control process that integrates several technologies to remove high levels of the primary air pollutants generated by coal-fired power plants. The four stages of ECO technology are:

Stage 1: A dielectric barrier discharge reactor that oxidizes NO and Hg
Stage 2: An ammonia based absorber that removes SO_2 and NO_2
Stage 3: A wet electrostatic precipitator used to collect aerosols and fine particles
Stage 4: A coproduct treatment system for removal of Hg and ash prior to producing commercial grade fertilizer

ECO is being demonstrated at the pilot scale using a slipstream drawn from FirstEnergy's R.E. Burger Power Plant near Shadyside, OH. The ECO pilot system, constructed at FirstEnergy's R.E. Burger Plant, has been in operation for over four years to support development of the technology. It was modified at the beginning of 2002 to incorporate the ammonia scrubber and its associated liquid handling equipment

The pilot, shown in Figure 1, draws a slipstream of gas from the Burger Plant's Unit 4 or 5, upstream of the unit's ESP. Units 4 and 5 each have an output of 156 MW and burn a blend of eastern bituminous and subbituminous coals. The coals used and the ratio at which they are blended vary depending upon the utility's needs. Flue gas from the pilot is returned to the unit at the ESP inlet. Flue gas entering the pilot, at a rate of 1500 to 3000 scfm (standard cubic feet per minute), passes through a small cyclone separator and two dry ESP fields, each four feet in length. These two units in series reduce the ash content to approximately 0.13 gr/dscf [2], which is approximately 10 to 15 times that measured at the outlet of the unit's ESP.

Upon exiting the dry ESP, flue gas enters a multi-tube, coaxial cylinder barrier discharge reactor. High voltage applied to the center electrodes of the discharge reactor

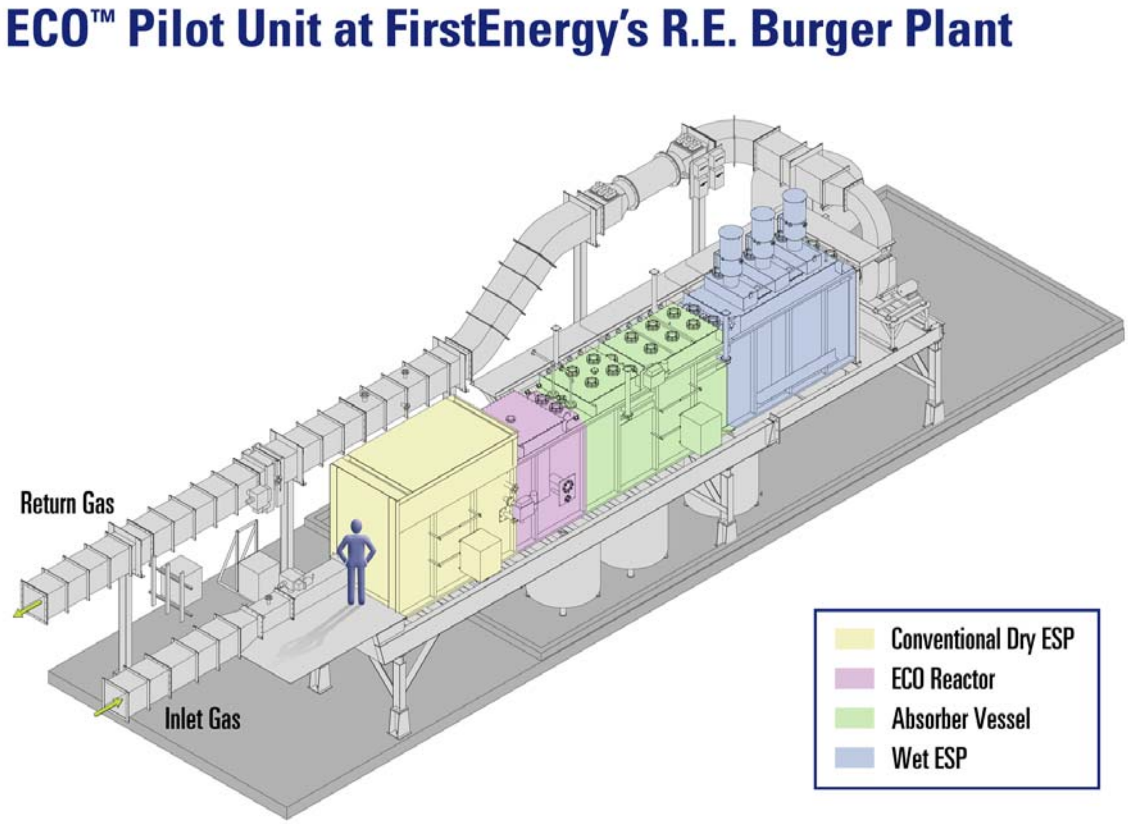


Figure 1: ECO Pilot Isometric Drawing

creates the non-thermal plasma that forms radicals leading to oxidation of gaseous pollutants. The ECO reactor is capable of delivering up to 100 KW of discharge energy to the gas.

The ammonia scrubber follows the barrier discharge reactor and is in an absorber vessel consisting of three packed sections in a cross flow configuration. The first section is 28" in the direction of gas flow. It cools and saturates the flue gas while concentrating the liquid coproduct. Next is a six-foot scrubbing section to remove SO_2 and NO_2. Following the scrubbing section is a six-inch packed section that absorbs gaseous ammonia exiting the scrubbing section.

Gas exiting the absorber vessel enters a horizontal, sectionalized, three-field WESP. Each field is thirty inches deep. The collecting plates are washed periodically, and the liquid effluent is sent to the ammonia scrubber section.

Ash and insoluble metals are removed from the liquid through filtration of the co-product stream. Mercury is removed from the co-product stream through the use of a sulfur-impregnated activated carbon bed.

An eight-man crew operates the Burger pilot on a three shifts a day basis. Continuous emissions monitoring is accomplished at the flue gas inlet and exit of the pilot. The system measures the concentration of SO_2, NO_x, O_2, H_2O, CO_2, CO and NH_3. Outlet flue gas flow and opacity are also measured continuously. Temperatures, flow rates, pH of all liquid streams, and pressure drop across all process units are also measured. In all, approximately 200 parameters are continuously recorded by automatic data logging equipment.

When the Hg SCEMS were integrated into the pilot unit, provisions were made to allow sampling at several points throughout the process. The sample points for the Hg SCEMS instrumentation are shown in Figure 2 and are at (i) the system inlet, (ii) between the dry electrostatic precipitator field and the dielectric barrier discharge reactor, (iii) between the discharge reactor and the scrubbing section, (iv) between the scrubbing section and wet electrostatic precipitator, and (v) the system outlet. The five sample ports are fitted with flanges to allow the sample probes to be moved from one location to another.

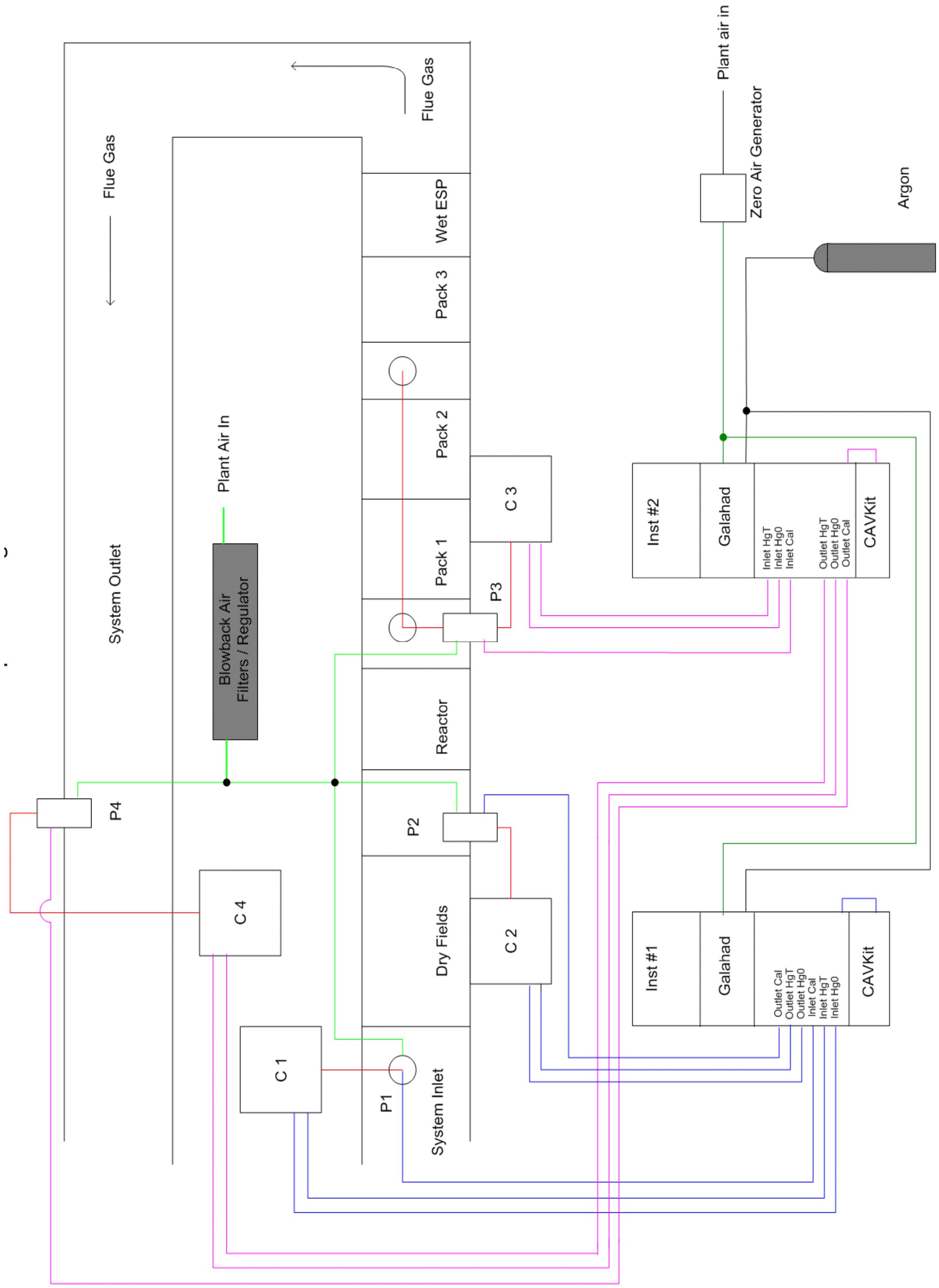


Figure 2: Schematic of mercury sampling system at the pilot.

4.0 Mercury Instrumentation

Since mercury measurement is an essential element in the development of any mercury removal process, Task 1 was spent investigating, selecting, installing, and validating the Hg SCEMS equipment. The requirements for the mercury instrumentation and sampling equipment were that (i) data could be collected on a near real time basis, (ii) instruments could differentiate between oxidized and elemental mercury, (iii) the instruments could be validated through periodic checks against Ontario-Hydro testing, and (iv) measurements would not be effected by constituents in the flue gas.

Parametric testing of the oxidation and removal of mercury in the ECO Process required several measurement points. The PS Analytical system was designed to accept samples from two locations through the use of stream switching and installation of sample probes and conditioning systems at each location.

In addition to gas-phase mercury measurement, ash loading measurements were made at the inlet of the ECO barrier discharge reactor and compared to the Burger Plant's reported ash loading on the outlet of the ESP. The results are shown in Figure 3; the red line is the measured ash loading on the outlet of the Burger Plant's ESP; the green triangles represent testing that show what was measured by Air Compliance Testing at the inlet of the ECO process using Method 5: (Determination of Particulate Matter Emissions from Stationary Sources), and the blue line shows the results of measurements made by Powerspan using an ash sampler at the inlet of the ECO process. The Powerspan ash sampler reports low compared to the Air Compliance Testing results obtained at the same time. However, the Powerspan Ash Sampler was designed only to give an indication of the day-to-day variations in ash loading at the inlet of the ECO pilot rather than as an isokinetic sampling system. The measurements show that the ash loading is consistently and substantially higher at the inlet of the ECO system than is present at the outlet of the Burger Plant dry electrostatic precipitator. The high ash loading is the likely cause of oxidation of Hg from the elemental Hg addition system and of contamination and speciation problems with the Hg sample probes.

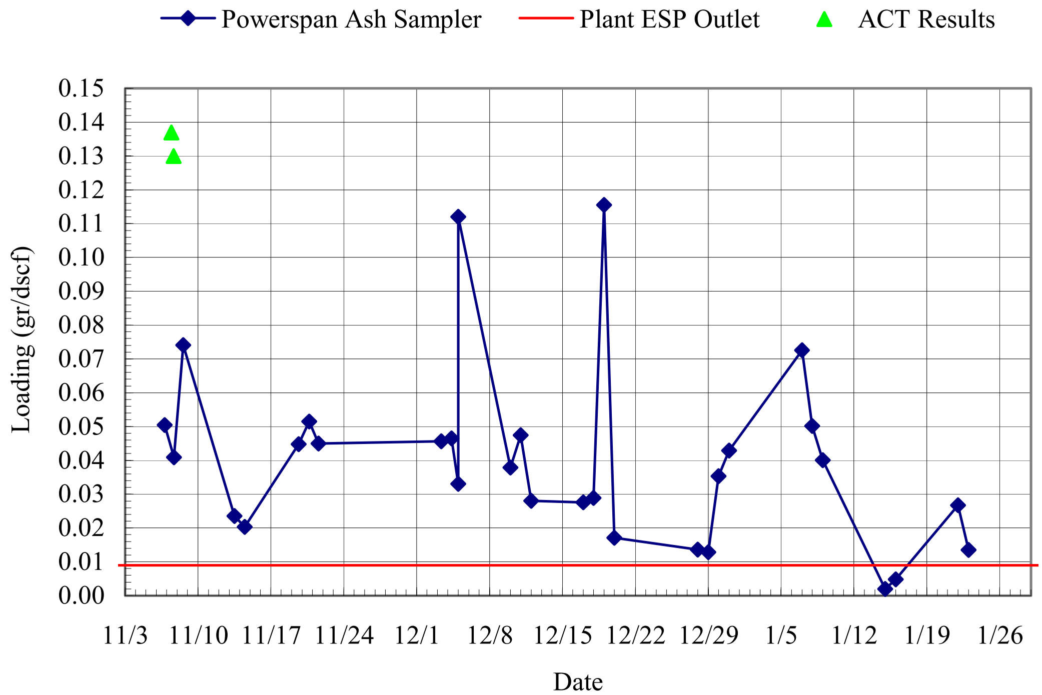


Figure 3: Ash loading measurements made at the ECO system inlet

4.1 Hg SCEMs Overview

Each Hg SCEM system is composed of two sample probes, two mercury speciation modules, an instrument rack containing a Sir Galahad II mercury analyzer, a stream selector and a CAVkit unit (calibration verification kit). The CAVkit is capable of delivering either zero-air or mercury spiked air to the sample probes for performing routine QA/QC tasks. A computer located in the instrument rack controls the Hg SCEM. A simple schematic of a typical system is provided in Figure 4 below.

The flue gas sample is drawn from the duct through a Teflon stinger and filter using a heated sample pump. The sample is then delivered to a Hg speciation unit with a heated sample line run at 400 ^{o}F to keep the stack gas temperature above the dewpoint and to keep oxidized Hg from adsorbing to the probe surfaces and sample lines. The flue gas sample is maintained at 400 F until being treated by the mercury speciation unit, where the sample stream is split into two parts, one for elemental Hg analysis and the other for total Hg analysis. After speciation, heated sample lines deliver conditioned flue gas to the stream selector to be analyzed in turn by the Sir Galahad analyzer. Sampling and analysis is controlled with software provided by PS Analytical on the computer located in the instrument rack.

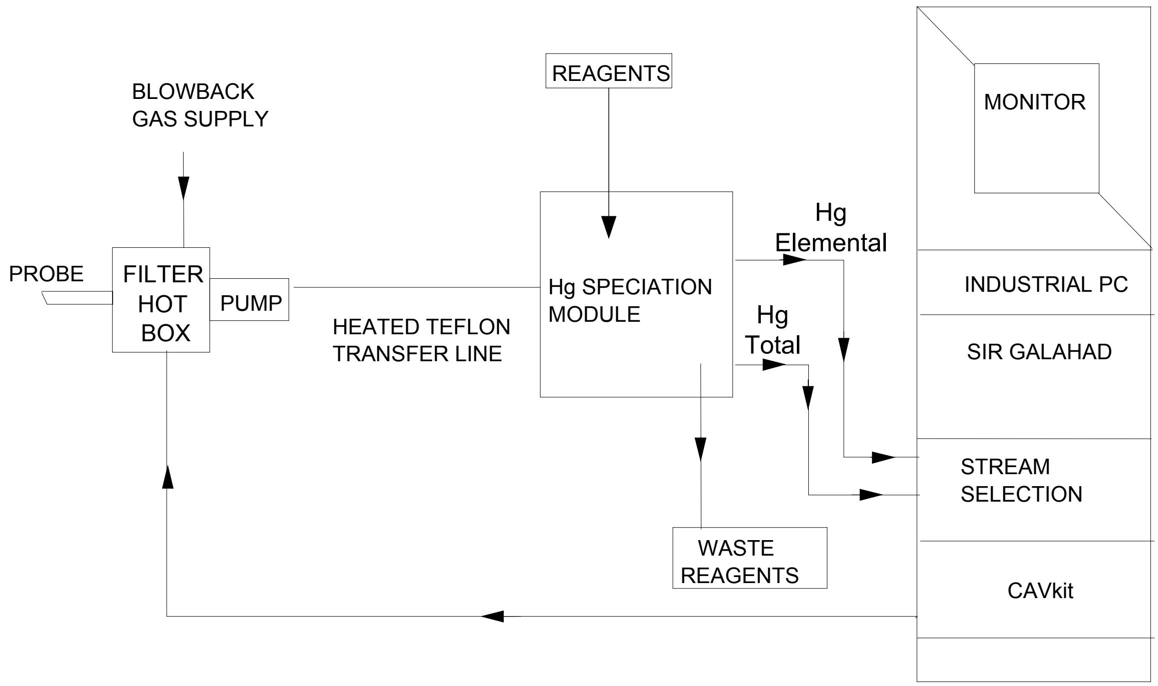


Figure 4: Schematic of a single probe Hg CEM.

4.2 Sample Probes

During this project, flue gas samples were extracted from the duct using two different sample probes. The PS Analytical sampling systems were delivered with Baldwin Environmental model 35Hg heated stack filter probes. The probes were installed at four locations in the ECO pilot. However, the inlet probe had numerous problems associated with ash in the flue gas and was replaced for a portion of the project with an Apogee Scientific Quick Silver Inertial Separation (QSIS) probe. The Apogee probe was used exclusively at inlet sampling locations and is specially designed for operating in high ash loading environments. The Baldwin sample probes were used occasionally on the inlet and always on the outlet of the system.

A schematic of a Baldwin sample probe is shown in Figure 5 and a picture of the probe is shown in Figure 6. The Baldwin probes contain filters to remove particulate matter larger than 2 microns in diameter. Each of the sample probes was fitted with a 0.5 in x 24 in Teflon stinger to acquire samples from the center of the ECO process duct.

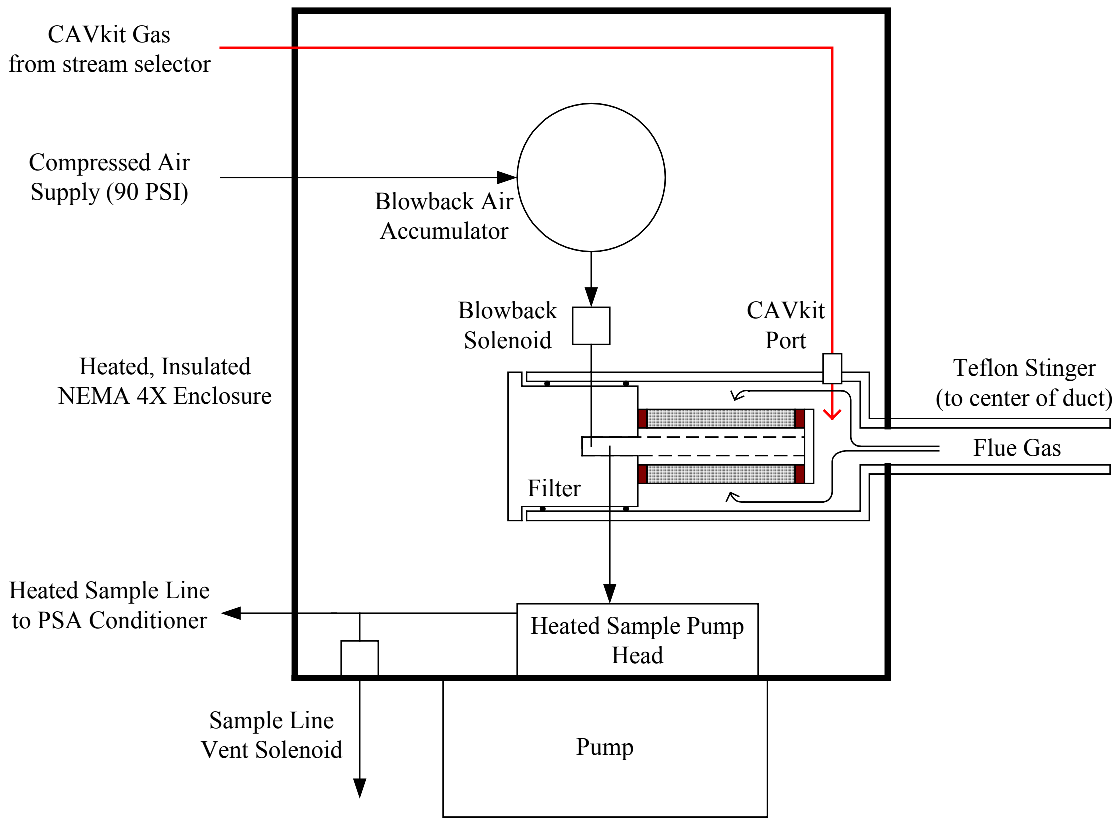
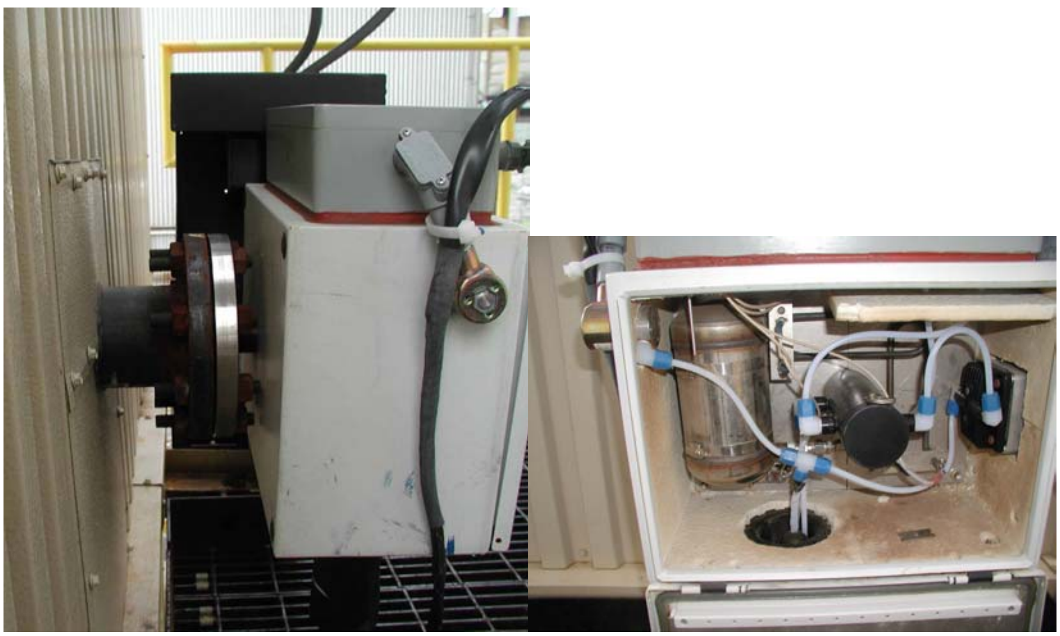


Figure 5: Schematic of a Baldwin Hg35 Sample Probe

Each Baldwin sample probe is enclosed in a NEMA 4X insulated, weatherproof, steel heated enclosure, with a heated head sample pump and filters to draw sample out of the duct and send it to the Hg speciation modules. The heated enclosure operates at 400 ^{o}F and is connected to the Hg speciation modules through a heated sample line also maintained at 400 ^{o}F. The pump is an integrated part of the sample probe. The entire assembly weighs approximately 80 pounds and is mounted on a standard ANSI flange assembly. A "blowback" feature is used to keep the filters clean of ash and other particulate matter. The timing of filter blowbacks depends on (i) the sample flow, (ii) the ash loading in the flue gas, and (iii) the characteristics of the ash; reactive to Hg or non-reactive to Hg. To operate, a blowback accumulator required a source of clean, compressed air (90 psi) that was periodically sent from the inside of the filter element to the outside. The loose ash on the outside of the filter is blown back into the ductwork. In addition to the blowback feature, the Baldwin Environmental sample probes have injection ports for the introduction of zero air and CAVkit gas. The zero air is Hg free air sent to the probe to determine whether Hg has contaminated the system. The CAVkit gas is a stream of elemental Hg sent to the probe tip to verify that oxidation of elemental Hg is not taking place on the filter and is discussed in more detail in section 4.6. Both the zero air and CAVkit gas were used for troubleshooting the Hg CEMs systems for leaks, contamination and malfunctions.



(a) (b)

Figure 6: A Baldwin Hg-35 heated sample probe (a) mounted to duct; (b) inside of heated sample box

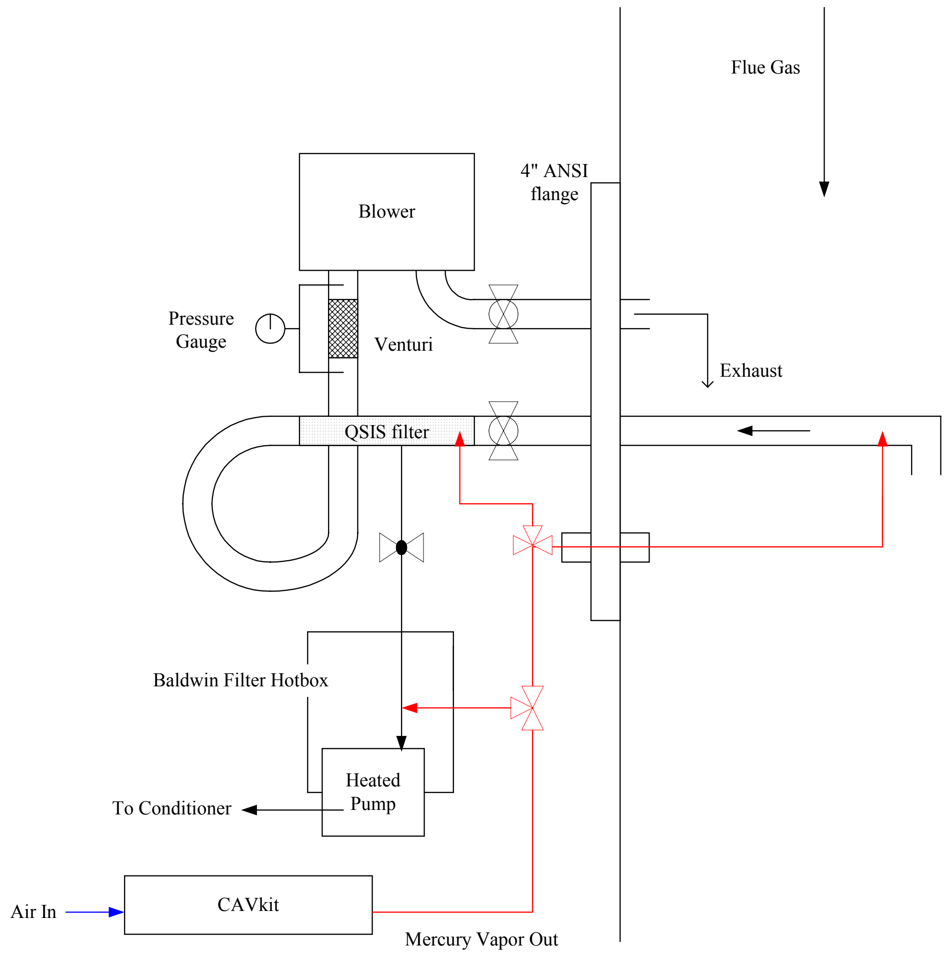


Figure 7: Schematic of the Apogee Scientific QSIS Probe installed at the Burger ECO pilot

A schematic of the QSIS probe is shown in Figure 7. The QSIS Probe System shown in Figure 8(a) used a modified Baldwin Environmental sample probe box to merge with the PS Analytical instruments and consists of the following (i) a QSIS Filter shown in more detail in Figure 8(b), (ii) a blower, (iii) heated sample pump, (iv) a venturi with a pressure gauge, (v) one 4-inch mounting flange with gasket, (vi) two isolation ball valves, (vii) two thermocouples, one measuring duct temperature, and measuring the probe temperature, (viii) two 110 V heaters, (ix) two box-enclosed PID temperature controllers, (x) and an insulated jacket.

(a)

(b)

Figure 8: (a) QSIS Sample Probe Assembly (b) Picture of filter element of QSIS Probe

The filter element and design of the QSIS probe prevent ash from being drawn into the sample stream. This is done by using a blower that moves the flue gas at high velocity through the 'racetrack' portion of the sample probe. Due to the high flow rate, particles are prevented from depositing and penetrating into the porous filter wall but gas can be drawn through. The filter is kept clean through a continuous 'scouring effect' where the ash drawn in from the duct, washes the filter off minimizing build up of ash. The filter pore size (2 μm) prevents particulate matter larger than the filter pore size from entering the flue gas stream. It is necessary to control the skin temperature of the QSIS filter to limit desorption of the particulate mercury in the bulk gas and absorption of vapor-phase mercury onto the fine particulate matter collected on the filter.

4.3 Hg Speciation Module and Sample Conditioner

The spectrometer in the Sir Galahad Analyzer can only measure elemental mercury, therefore it is necessary to use a sample conditioning unit to convert oxidized mercury into elemental mercury. The Hg speciation module and sample conditioner (i) uses wet chemistry to differentiate between elemental and oxidized mercury, (ii) removes water from the sample stream to protect the analyzer and maintain the integrity of the sample, and (iii) provides a heated enclosure to split the flue gas into two streams. A schematic and picture of a sample conditioner is shown in Figure 9 **and Figure 10** below.

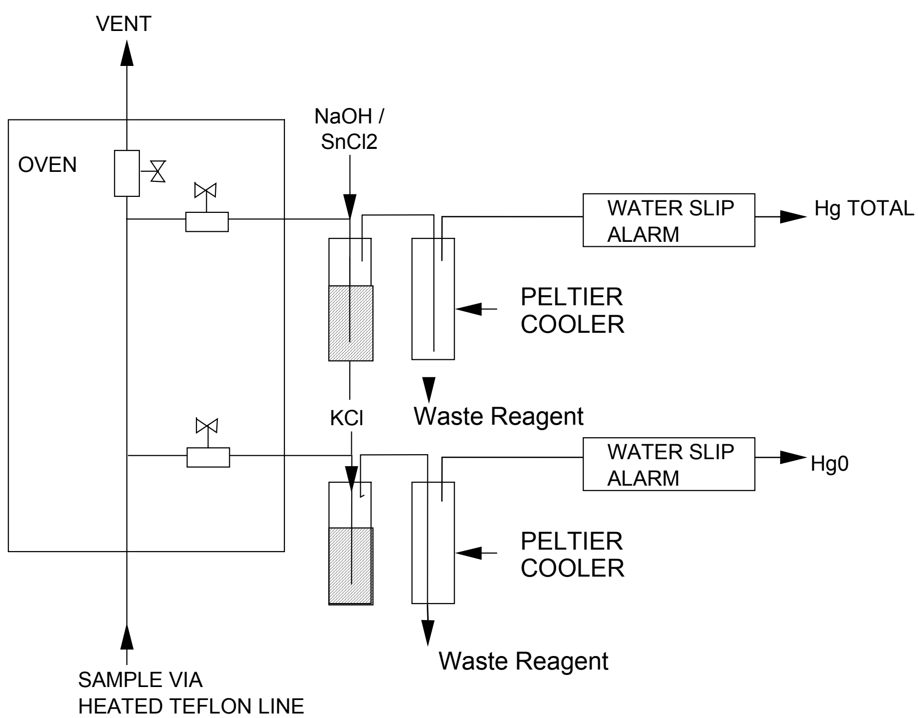


Figure 9: A flow schematic for a PS Analytical conditioning unit

Flue gas is pumped from the sample probes to the sample conditioner using the probe's heated head pump. It is necessary to insure excess flow is sent to avoid diluting the flue gas stream and underreporting Hg concentrations. The flue gas enters the sample conditioner and is split into two streams that bubble through two impingers, one for

Figure 10: Photograph of an installed PSA conditioning unit

elemental Hg measurement and one for total Hg measurement. Teflon valves are used to control the amount of flow going to each of the channels and the vent. The impingers contain reagents specific to each channel as discussed in more detail below, and are filled and emptied using Teflon capillaries and a peristaltic pump. The flue gas continues through a Peltier Cooler that removes moisture and decreases the dewpoint of the flue gas to 5°C. Before being sent through a heated sample line to the analyzer the flue gas goes past water slip detectors which are designed to shut off the pumps in the event that liquid is present in the sample stream. Liquid in the sample stream can result in costly damage to downstream components in the stream selector and analyzer.

The wet chemistry used to speciate mercury is split up into an elemental channel and a total channel. The elemental channel uses a 10% potassium chloride (KCl) solution. This allows oxidized mercury to be captured in the impinger while elemental mercury passes through the rest of the sample conditioning into the analyzer for measurement. The total channel uses a 2% stannous chloride ($SnCl_2$) solution made in 25 wt% NaOH. The elemental mercury will pass through the solution and the oxidized Hg will be reduced to elemental Hg by the $SnCl_2$ solution and also be measured by the analyzer. The difference in mercury concentration between the total Hg channel and elemental Hg channel is the amount of oxidized Hg in the flue gas. The impinger solutions are also designed to remove acid gases that would degrade the performance of the gold trap, such as SO_2, NO_2, HCl, and HF.

The reagents are constantly pumped into the impingers and are stored in, 10-liter reservoirs underneath the conditioning units. Each conditioning unit requires 2 L of KCl solution and 5 L of NaOH/$SnCl_2$ solution per channel per day. Since the PS Analytical instrument is able to detect very low levels of mercury, it is important to use high quality reagents to make the impinger solutions. The NaOH is ACS grade (J.T. Baker) with a maximum of 0.5 ppb trace metals, the KCl is ACS grade (Acros), and the SnCl2 is also ACS grade (J.T. Baker). The procedures for preparing reagents are in Appendix A.

4.4 Stream Selector

In addition to the analyzer, each instrument rack is equipped with a 16-channel stream selector shown in Figure 11. This stream selector allows numerous sample streams to be monitored with the same analyzer by switching to a different stream. The stream selector consists of 8 three-way Teflon switching valves and a digital mass flow controller that regulates the flow of flue gas over the Amasil trap in the Sir Galahad II analyzer. In standby mode, all the sample streams flow to waste and the valves are de-energized. Valves are activated using the TTL line from the Sir Galahad. When a stream has been selected for analysis, the corresponding valve is energized using 12-volt dc signal. In addition to sampling from any of four gas streams (Channel 1 Hg(0), Channel 1 Hg(T), Channel 2 Hg(0), Channel 2 Hg(T)) the stream selectors are also capable of directing zero air and CAVkit gas to the appropriate sample probe.

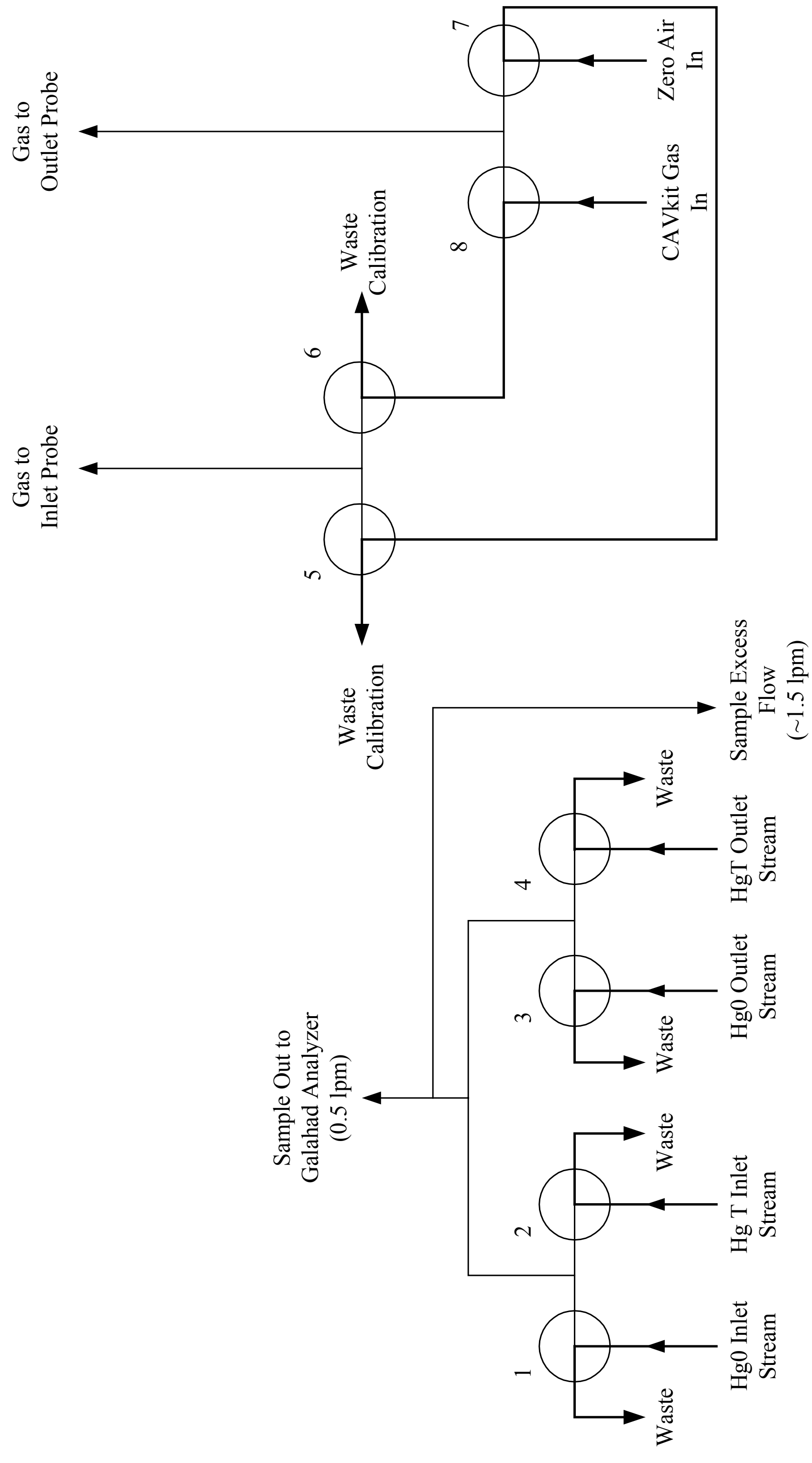


Figure 11: Schematic of a PS Analytical stream selector

4.5 Sir Galahad II Analyzer

The Sir Galahad II analyzer uses an atomic fluorescence spectrometer to detect elemental mercury. Atomic fluorescence is a radiational de-activation process that occurs after the excitation of free atoms by the absorption of radiation of a characteristic wavelength from an appropriate excitation source. There are several advantages of using atomic fluorescence spectrometry (AFS) to detect elemental mercury. These include (i) attainable sensitivity that is controlled by the intensity of the excitation source, (ii) the equipment can be less complex than that needed for atomic absorption spectroscopy (AAS) or atomic emission spectroscopy (AES), (iii) good linearity, (iv) low spectral interference, (v) high selectivity, (vi) sensitivity into the far UV whereas AAS and AES insensitive and (vi) analytical line summation. There are several disadvantages of using AFS however. These include (i) quenching form gaseous species, (ii) scattering from the light source, and (iii) self absorption at high concentrations.

The intensity of fluorescence produced can be expressed by the following equation

$$I_f := I_o \cdot W \cdot \frac{\Omega}{4 \cdot \pi} \cdot A_t \cdot \phi$$

Where:

I_f = Intensity of fluorescence

I_o = Radiant flux

W = Width of exciting beam of radiation

Ω = Solid angle

A_t = Total absorption factor at the fluorescence line

ϕ = Fluorescence yield (fraction of the absorbed photons which are re-emitted as fluorescence radiation

Utilizing the advantages of atomic fluorescence, the Sir Galahad II analyzer is capable of determining elemental mercury masses to 0.1 picograms.

To make a measurement of elemental mercury, a gold impregnated silica (Amasil) trap is used to adsorb mercury from the flue gas. Using an Amasil trap, the Hg is pre-concentrated to produce a signal that is easily measured and calibrated to by the analyzer.

Flue gas is drawn over the trap at a flow rate of 0.5 L/min, which is regulated by the mass flow controller in the stream selector, for an amount of time pre-determined for the expected Hg concentration to be measured. The sample time can vary from one to five minutes, but for testing done in this project, the typical sample times were one minute. Once sampling is completed, the trap is flooded with argon and the Amasil trap is heated to re-vaporize the mercury and carry it into the analyzer. The elemental Hg is carried past a mercury vapor lamp producing fluorescence. The fluorescence produced is measured by a conventional photomultiplier tube (PMT) creating a signal. The signal is proportional to the concentration of Hg in the sample. Argon is the preferred carrier gas since it does not quench the fluorescence signal produced, as is done by nitrogen or air.

Calibration of the analyzer involves injection of a known amount of mercury vapor onto the gold trap. This is a simple but effective means of providing a primary standard, and is more effective than alternative diffusion tube approaches. The calibration is based on the vapor pressure of mercury, which is well known. A specially designed glass vessel, shown in Figure 12, is used to (i) contain the mercury, (ii) measure the temperature of the mercury vapor, and (iii) allow Hg vapor to be drawn out of the vessel in a syringe. Mercury from the calibration vessel is injected onto the Amasil trap.

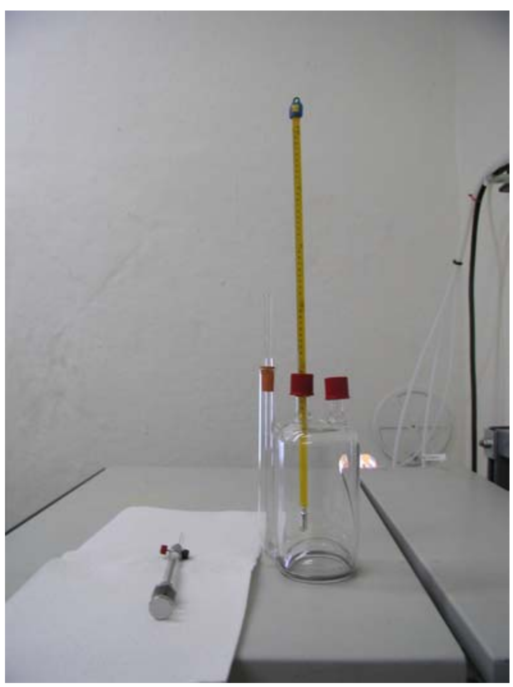


Figure 12: Glass Calibration Vessel

The Hg is then re-vaporized and carried to the detector just like a flue gas sample, where the peak height or peak area of the response is measured. A calibration curve is generated by plotting the instrument signal against the injected mass of mercury for several mercury concentrations. The PSA software calculates the expected Hg concentration for the calibration based on the temperature and volume used for the calibration spike. The temperature is measured to ± 0.1 °C. A typical calibration curve is shown in

Figure **13**. Problems with the calibration that require further investigations are (i) the slope of the calibration curve has changed by more than 10% from the last calibration, (ii) the calibration curve intercept is >± 50 a.u, or (iii) the correlation coefficient is < 0.999. The calibration failures seen during the course of this project were resolved by maintenance on the calibration vessel, syringe replacement, septa replacement and maintenance on the analyzers.

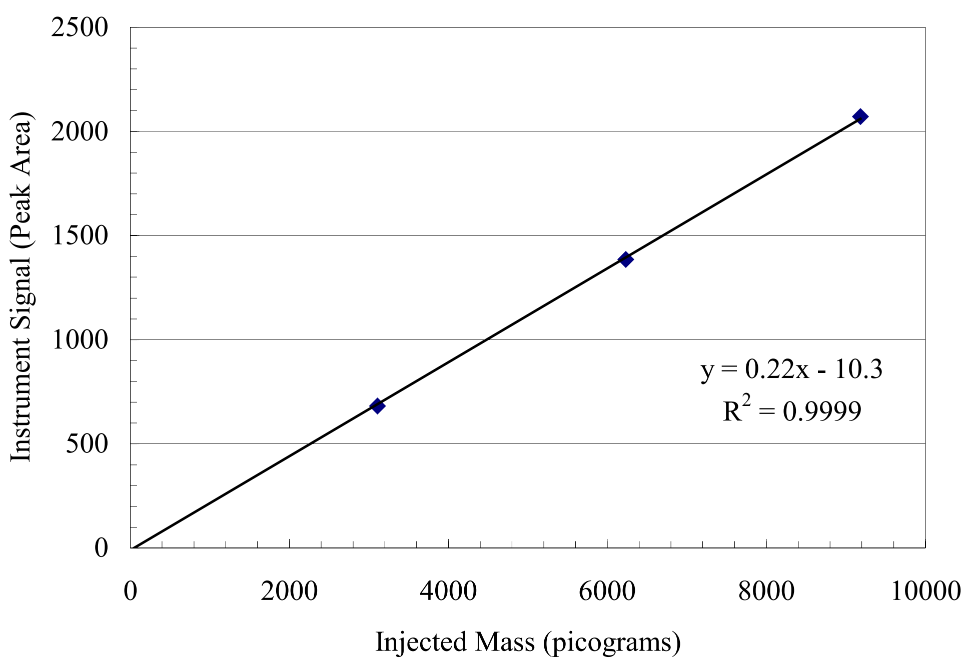


Figure 13: A typical calibration curve for the Sir Galahad mercury analyzer

4.6 CAVkit Unit

The CAVkit unit is a device for generating elemental mercury vapor that can be sent out to the Hg SCEMS sample probes. A schematic of the CAVkit unit is shown below in

Figure **15**. A supply of mercury-free air produced with a Domnic-Hunter Zero

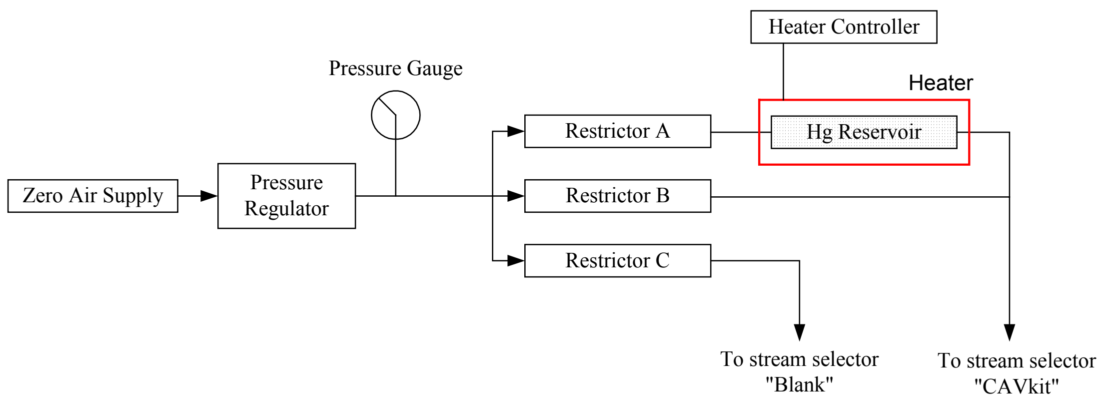


Figure 15: Schematic of CAVkit unit

Air Generator is connected to the CAVkit unit and controlled to a pressure of ~25 psi with a pressure regulator. The zero air generator incorporates several filters, one of which is a charcoal filter used to filter out mercury vapor. To generate elemental mercury, this zero air is sent through a small reservoir which contains ~15 grams of elemental mercury adsorbed onto an inert substrate. Changing the temperature of the mercury reservoir will vary the elemental Hg output from the CAVkit due to the change in mercury vapor pressure. The CAVkit unit, under normal operating conditions, can generate a maximum of 20 $\mu g/Nm^3$ of elemental mercury at a flow of 16 lpm. The CAVkit is also capable of sending just the zero air to the sample probes that can be used to perform instrument blanks.

A shortcoming of the CAVkit units purchased was the inability to exactly quantify the amount of elemental mercury being sent to the sample probes. In the CAVkit unit, Restrictor A controls the flow through the reservoir forced by the pressure drop across Restrictor B. Any minor pressure changes at the CAVkit inlet or outlet changes the split ratio of the flow between Restrictor A and Restrictor B and therefore the concentration of elemental mercury vapor generated. Therefore, the elemental Hg can only be estimated and verified through consistency from run to run. Towards the end of the program, an upgraded CAVkit unit became available for use with the PS Analytical system that can generate a known quantity of mercury vapor to within ±5% of expected values. Due to limited resources and time remaining in the program, we opted not to purchase the upgrade.

4.7 Hg SCEMS Operations

There are several QA/QC checks that are conducted with the Hg SCEMS in order to verify system integrity, reliability and accuracy. These include (i) calibration of the analyzers, (ii) detector checks, (iii) running blanks and elemental mercury spikes on the inlet sampling system, (iv) running blanks and elemental mercury spikes on the outlet sampling system, and (v) checking operation of the system mass flow controllers.

The Sir Galahad II analyzers used in the Hg SCEMS are calibrated once every forty-eight hours as described above in Section 3.5. The range of mercury concentration used during an analyzer calibration spans the concentrations observed in the flue gas and are typically from 1 to 20 $\mu g/Nm^3$. During each calibration, the instrument response curve is examined. It has been found that unusual response curve morphology is indicative of an Amasil trap fouling or failure. Additionally, the slope, intercept, and correlation coefficient for each calibration are stored and added to a trending plot. Results and plots of the analyzer calibration curves are routinely kept as part of the Hg SCEMS QA/QC documentation.

The second QA/QC event for the analyzers in the Hg SCEMS is to undergo daily detector tests where the mercury lamps and photomultiplier tubes in the optics units are checked. The daily detector tests are run in order to identify problems with both the mercury vapor lamp and the photomultiplier tube in the analyzer. During the detector test, the mercury vapor lamp emission intensity is checked. A sudden drop in intensity from day to day is an indication that the mercury lamp is failing and needs to be replaced. The response of the photomultiplier tube at several gain settings is also checked. A change in PMT response as a function of time is an indication that the PMT may be failing or that the optics unit in the analyzer is becoming dirty. The data from these maintenance tasks are kept and the trend lines are examined daily to check for correct operation.

An end-to-end test on the sampling system is conducted every forty-eight hours to verify two things: (i) there is no Hg contamination in the system and (ii) elemental mercury is not being oxidized by reactive ash. The blanks done to check for mercury contamination are conducted by pulling zero air through the sample train. This can be done on any Baldwin Environmental sample probe that is operating in the pilot unit. To run blanks on the Baldwin Environmental sample probe, zero air is sent from the instrument rack to the filter housing. It is necessary to push more air into the sample chamber than the sample pump draws from the duct to insure flue gas does not get pulled into the zero air and bias the results. An analysis of the gas stream is done by passing the zero air over the Amasil trap and re-vaporizing the mercury for detection. An acceptable blank produces zero air mercury concentrations of <0.25 μg/Nm^3 when pulled through the sample train. An example is shown in Figure 17. When mercury contamination is found, the contaminated components are cleaned with a 10% nitric acid (HNO_3) solution followed by repeated rinsing with deionized water. This has proven a successful way to eliminate Hg contamination in the sample train.

A further check of system operation involves using the CAVkit unit to send elemental Hg to the sample probe tip to be pulled through the sample train. Results from a successful CAVkit run are shown in

Figure 18. To conduct a CAVkit check, the temperature of the mercury reservoir is set to 60 °C and the pressure regulator on the CAVkit is set to 30 psi. A gas stream composed of ~10 μg/Nm^3 of elemental mercury floods the filter housing. This gas is then drawn through the entire sampling system and the mercury content is measured at the Sir Galahad analyzer. In a successful CAVkit test, the measured levels of elemental and total mercury concentrations agree to within 5% of each other and the measured values of mercury from test to test must be consistent. The PS Analytical CAVkit unit used in this project is not set up to give a quantifiable amount of elemental Hg. Therefore, the elemental Hg can only be estimated and verified through consistency from run to run.

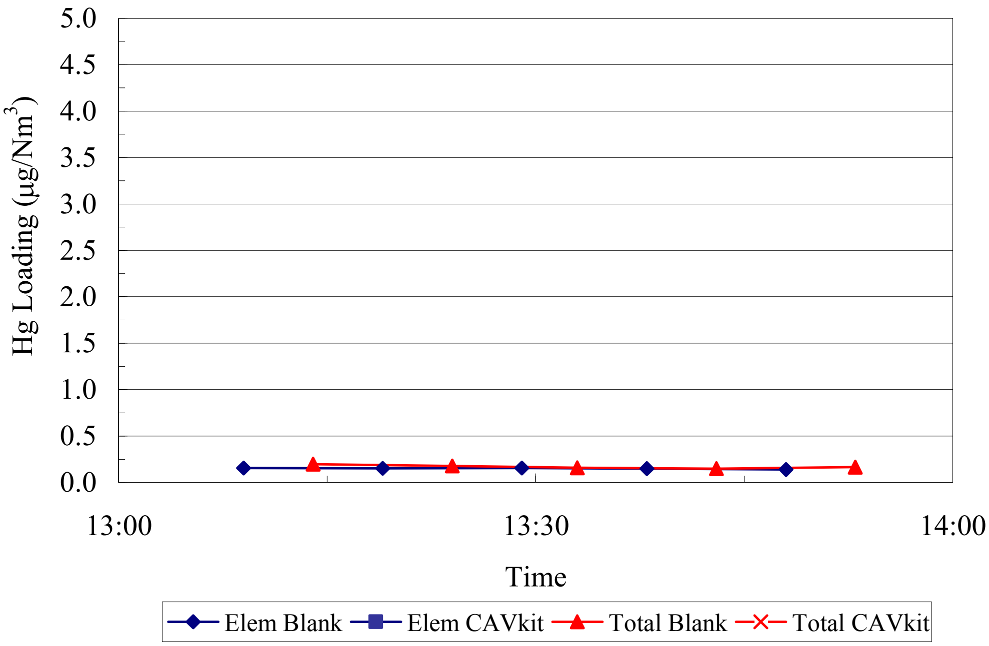


Figure 17: Results of a blank showing no Hg contamination in the sample train on the outlet of the pilot system.

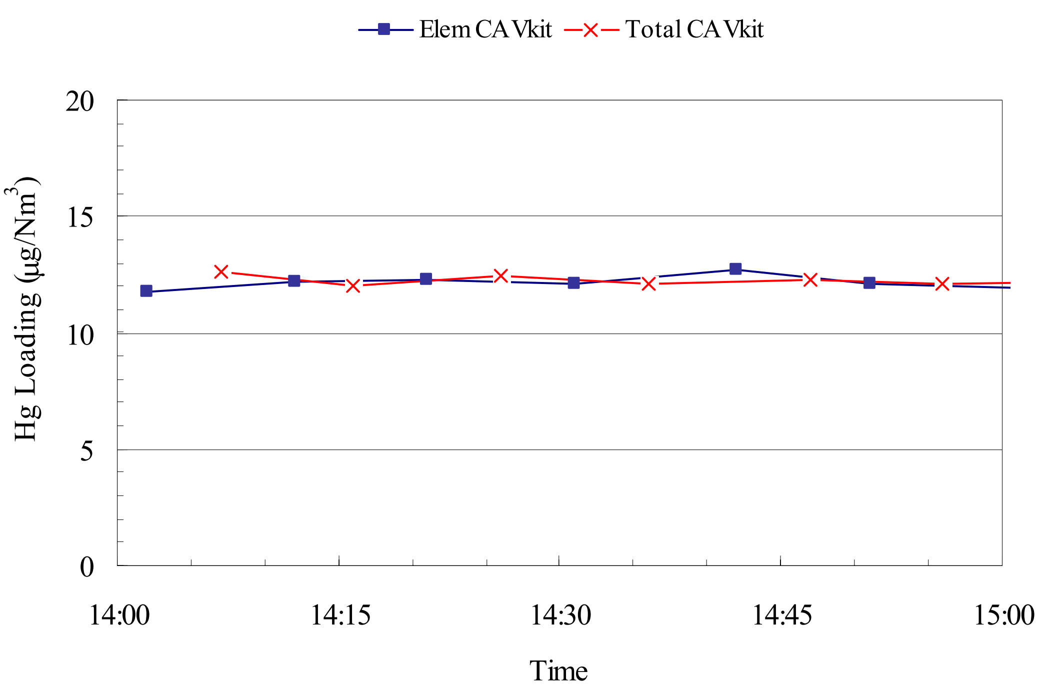


Figure 18: Results of a CAVkit test verifying no oxidation of elemental mercury through the sampling system on the outlet pilot system.

During this project, the CAVkit mercury concentration usually ran at 10 ± 4 μg/Nm^3. A failure of the CAVkit test indicates one of many problems with the instrumentation including (i) reactive ash on the filter, (ii) sample flow regulation problems, (iii) sample line leaks, (iv) sample line contamination by ash, or (v) hardware problems such as mechanical failures in the stream selector. A series of CAVkit test failures occurred on one occasion when the Teflon coating on the heated sample probes failed and peeled off. Each failure must be investigated and corrected on an individual basis. Typical spike and blank runs last anywhere from 30 minutes to one hour.

An Apogee QSIS probe was used for a portion of this project in place of the Baldwin Environmental sample probe to sample the inlet gas to the pilot unit. As described above, the QSIS probe used a modified Baldwin Environmental sample probe to merge with the PS Analytical instrumentation. Due to this modification, the QSIS probe and CAVkit needed to be modified to be able to run elemental mercury spikes and blanks on the probe. To run a blank on the QSIS probe, the probe samples ambient air for several measurement cycles of elemental and total mercury. If no contamination is present the result shows the concentration of the elemental and total mercury channels of <0.25 μg/Nm^3. CAVkit spikes on the QSIS probe are run in a similar manner, with the exception that gas from the portable CAVkit is injected into the tip of the QSIS probe stinger (see Figure 20). For the QSIS probe spikes, the CAVkit Hg reservoir temperature is set to 60 °C and the CAVkit pressure set to 30 psi. Figure 21 presents the results of a typical QSIS probe blank and CAVkit spikes set for both elemental and total mercury channels. It is a requirement that no flue gas be running to perform the blanks and CAVkits on the QSIS probe because of the inability to (i) provide enough zero air to the probe tip to not pull flue gas in with the sample, and (ii) quantify the dilution that would take place for verifying the proper Hg being delivered to the probe tip.

These tests are usually performed prior to the pilot startup and after shut down. The criteria for acceptable blanks and CAVkits are the same for the inlet sampling system end-to-end tests as the outlet sampling system. For verification of results during testing when flue gas is running and the end-to-end checks cannot be performed, blank and spike tests are conducted on the inlet sample system downstream of the QSIS probe, but prior to the heated sample pump every forty-eight hours. As seen in Figure 20, sampling here allows some of the sample train to be checked for contamination and reactive ash build up. However, it does not allow the filter element to be checked for reactive ash build up.

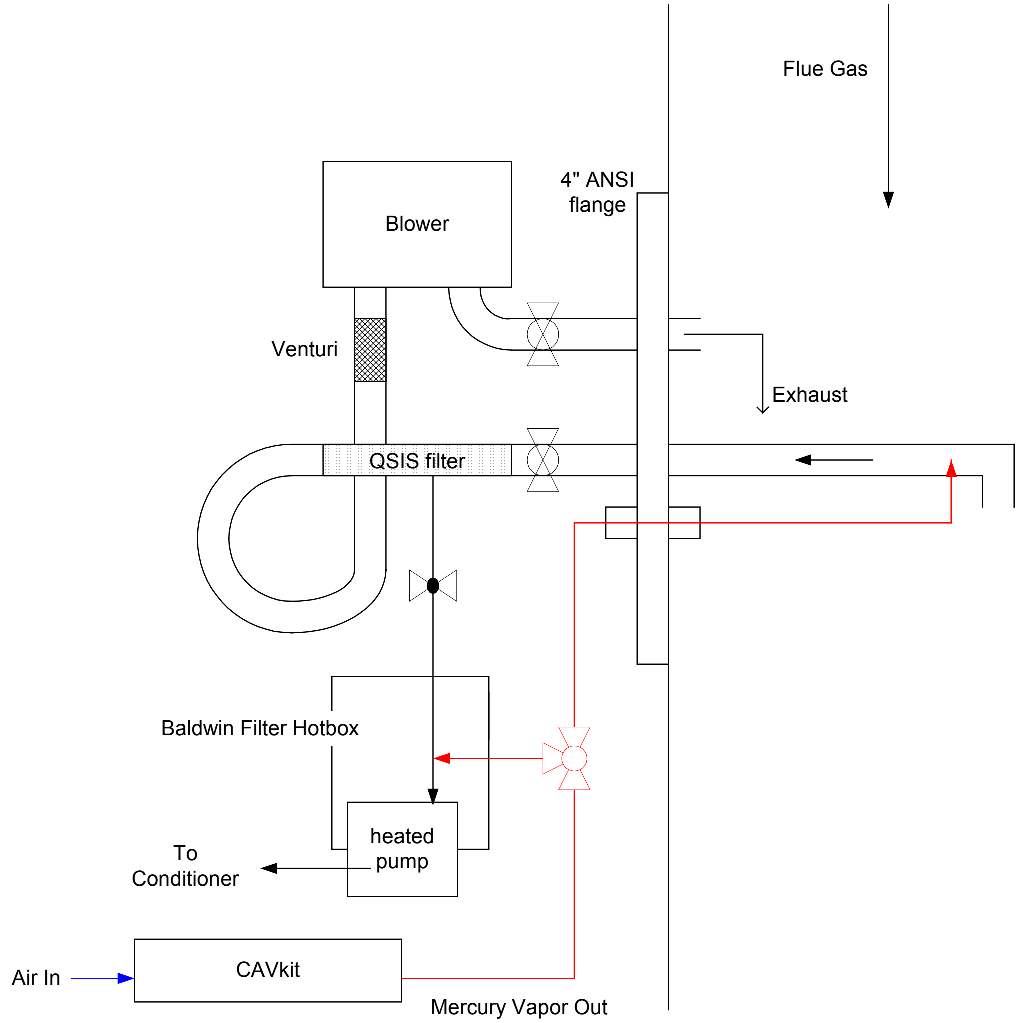


Figure 20: Schematic for spiking the QSIS probe with elemental mercury

The final check of the QSIS filter must be performed after finishing the test and shutting down the pilot unit. There is often a small amount of oxidation occurring through the QSIS filter in the high ash loading environment, as shown in Figure 21. By using the CAVkit testing, the sampling bias can be estimated. The sampling bias is the amount of mercury that is oxidized in the QSIS filter expressed as a percentage. Table 1 shows a summary of the sampling bias for CAVkit checks shown in Figure 18 and Figure 21.

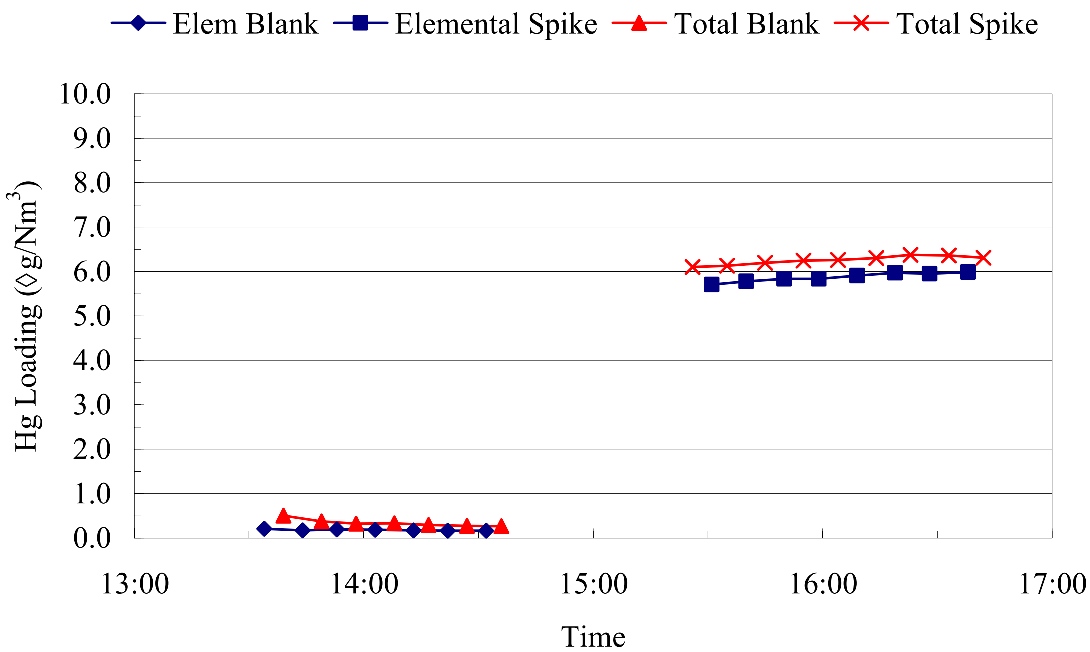


Figure 21: Typical blanks and CAVkit spikes for the inlet sampling system using a clean QSIS filter

Check	Inlet µg/Nm^3	Outlet µg/Nm^3
Elemental Hg Blank	0.18 ± 0.02	0.15 ± 0.01
Total Hg Blank	0.27 ± 0.08	0.17 ±0 .02
Elemental Hg CAVkit spike	5.87 ± 0.10	12.17 ± 0.28
Total Hg CAVkit spike	6.13 ± 0.27	12.25 ± 0.19
Bias	1.8% (Total Hg)	0.48% (Total Hg)

Table 1: Results from a quality control check on the inlet and outlet Hg sampling system

It is important to verify the sample bias on the system so that the oxidation of elemental mercury by the reactor will not be over or under reported depending on which probe is exhibiting the bias. Table 1 shows typical bias results for a clean system, but the bias can be significantly increased by contamination of the system by reactive ash.

Since the pilot must be shut down while CAVkit and blank checks are performed on the QSIS probe, methods to dynamically check portions of the probe while the pilot is operating have been developed. To do so, elemental mercury vapor from the CAVkit is injected directly into the flue gas flow going through the QSIS filter. If there is no sampling bias between the elemental and total mercury channels, the increase in measured mercury in both channels will be the same. The results of a typical dynamic spike run are presented in Table 2.

	Average Elemental Hg $\mu g/Nm^3$	Average Total Hg $\mu g/Nm^3$
Baseline Measurements	0.36 ± 0.03	10.1 ± 0.81
Spiked Measurements	5.43 ± 0.19	15.15 ± 0.27
Increase	5.07 ± 0.19	5.04 ± 1.3

Table 2: Results from QSIS probe dynamic spiking test.

The results show elemental mercury is not oxidized between the filter and the detector. Had the elemental mercury been oxidized on its way to the analyzer through the QSIS probe and sampling system, the total Hg measurement would have shown a larger increase in mercury than the elemental mercury measurement. Instead, the increase of elemental and total mercury was the same, indicating no oxidation was taking place after the filter.

Missing from all the spike tests, however, is the ability to calibrate the entire sampling systems by injecting known amounts of elemental and oxidized mercury vapor into the sample probes. The CAVkit units are capable of generating only approximately consistent values of elemental mercury and there is currently no oxidized Hg validation procedure that can be used.

5.0 Hg SCEMS Instrument Validation

Two methods were used to validate the PS Analytical SCEMS equipment; (i) Ontario-Hydro Testing, and (ii) batch sampling with a remote trap and analysis with the PS Analytical detector. Air Compliance Testing Inc. (ACT) conducted three days of baseline validation testing of the installed Hg SCEMs systems. The validation testing involved twenty-three hours of testing using the Ontario-Hydro Method during May 8-10, 2002. See Appendix B for detailed information about the Ontario-Hydro method. During the testing, the two PS Analytical Hg SCEM systems were operated using Baldwin Environmental sample probes at the system inlet and outlet. During testing, the PS Analytical instruments alternated between Elemental Hg and Total Hg measurements every five minutes. A blank was obtained prior to the testing event to allow the measurements to be blank subtracted and averaged over the time period of the ACT testing run. Calculations of oxidized mercury levels were made by subtracting the PSA elemental Hg levels from the PSA total Hg levels.

For comparison, ACT collected three samples at the system inlet consisting of one three-hour run and two four-hour runs and three samples at the system outlet each consisting of four hours runs. A comparison of the data obtained by the PS Analytical instruments and ACT is provided in Table 3 below. The PS Analytical total and elemental Hg measurements were subtracted to give the oxidized Hg concentration which is reported below in Table 3.

	PSA Elemental µg / dscm	ACT Elemental µg / dscm	ACT Hg^0 Detection Limit	PSA Oxidized µg / dscm	ACT Oxidized µg / dscm	ACT Hg^{2+} Detection Limit
Inlet Run 1	0.53 ± 0.10	<0.52	0.52	3.96 ± 0.68	5.28	0.22
Inlet Run 2	0.06 ± 0.03	<0.35	0.35	4.68 ± 0.75	5.70	0.26
Inlet Run 3	0.19 ± 0.07	<0.42	0.42	5.74 ± 0.75	6.46	0.27
Outlet Run 1	0.58 ± 0.10	0.58	0.48	0.15 ± 0.04	<0.37	0.37
Outlet Run 2	0.40 ± 0.05	0.58	0.38	0.13 ± 0.04	<0.32	0.32
Outlet Run 3	0.45 ± 0.03	1.09	0.37	0.15 ± 0.05	<0.31	0.31

Table 3: Comparison of Air Compliance Testing and Powerspan Hg SCEMS results.

On the inlet, the elemental Hg measured by ACT was below the detection limit (BDL) of the method and the PS Analytical instruments reported 0.53, 0.06, and 0.19 μg/Nm^3, which confirm the measurements were BDL. For oxidized Hg, ACT measured 5.28, 5.70, and 6.46 μg/Nm^3 compared to 3.96, 4.68, and 5.74 μg/Nm^3 measured by the PS Analytical instruments in Inlet Run 1, 2, and 3, respectively. The oxidized Hg concentration increased for both ACT and the PS Analytical instruments from Run 1 to Run 3. The average error in the PS Analytical instruments compared to the ACT measurements was 18% for the oxidized Hg measurement on the inlet.

On the outlet, the elemental Hg measured by ACT was 0.58, 0.58, and 1.09 μg/Nm^3 compared to 0.58, 0.40, and 0.45 μg/Nm^3 measured by the PS Analytical instruments in Outlet Run 1, 2, and 3, respectively. The outlet oxidized Hg measured by ACT was BDL and measured by the PS Analytical instruments was 0.15, 0.13, and 0.15 μg/Nm^3 for Outlet Run 1,2, and 3 respectively. The average error in the PS Analytical instruments compared to the ACT measurements was 29% for the elemental Hg measurements on the outlet. However, if Run 3 is considered an outlier due to the large increase in elemental Hg seen, the average error decreases to 11%.

This testing data suggests a reasonable agreement between the Ontario-Hydro method test results and the Hg SCEMS test results. The complete results for the ACT test event are included in Appendix C and a brief summary of performance is shown in Table 4.

Hg Fraction	**ECO Inlet**	**ECO Outlet**	**Removal**
Particle Bound Hg (μg/dscm)	0.62	0.016	97.4 %
Oxidized Hg (μg/dscm)	5.81	0.022	99.6 %
Elemental Hg (μg/dscm)	0.16	0.75	
Total Hg (μg/dscm)	6.59	0.79	88.0 %

Table 4: Summary of Ontario-Hydro Test

A second method has also been developed for routine validation of the data being collected with the PS Analytical instruments. An external remote gold trap is used to collect mercury independent of the PSA conditioners and Baldwin probes. By using the remote trap, the measured mercury concentrations can be verified independently of the PSA sample train and on a routine basis.

A schematic of the batch measurement system is shown below in Figure 22. A

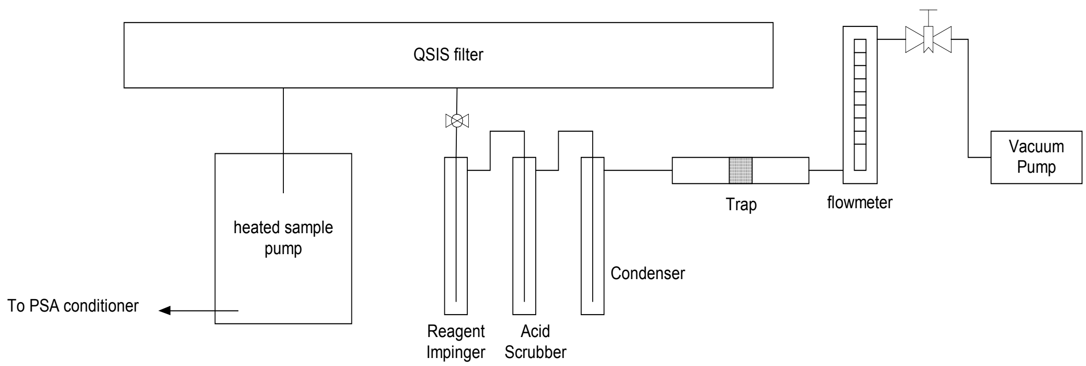


Figure 22: Flow schematic of the batch sampling system attached to the QSIS probe.

vacuum pump is used to sample off the QSIS probe in parallel with the PS Analytical instruments. The flue gas is pulled through a series of impingers to speciate the mercury, remove acid gases, and remove moisture. The reagent impinger, the first in the series, is filled with 10% KCl for elemental mercury analysis or 1% $SnCl_2$ in 0.5N H_2SO_4 solution for total mercury analysis. The acid scrubber impinger contains 10 wt% NaOH to scrub out acid gases and finally, the condensing impinger is an empty impinger cooled in an ice bath to remove moisture from the flue gas stream. The flue gas is then passed over a portable Amasil trap to adsorb mercury, similar to what occurs inside the PS Analytical instruments. It is necessary to record gas flow and sample time to convert the mercury mass to a flue gas concentration. Measurement of the captured mercury is made using the external "remote" sample port provided with the PS Analytical Sir Galahad instruments. Once attached to the remote sample port, the analysis of the mercury is the same as described above in Section 3.4. Since these results are being used to check the semi-continuous measurements made with the PS Analytical sample trains, testing of the batch sampling method was done to verify it was an acceptable check of the Hg SCEMS. The checks that were done are (i) injections of known amounts of mercury onto the remote traps, (ii) spikes of elemental mercury into the flue gas stream being sampled, and (iii) simultaneous sampling of the PS Analytical sample train and the batch sample train with CAVkit gas.

The first check is to verify that the remote trap is able to capture and report all of the mercury injected onto the trap. The mercury calibration vessel was used to obtain known amounts of elemental mercury vapor to inject directly onto the remote trap. Once the mercury had been captured on the portable Amasil trap, the remote trap port of the Sir Galahad detector was used to measure the mercury. Figure 23 below illustrates

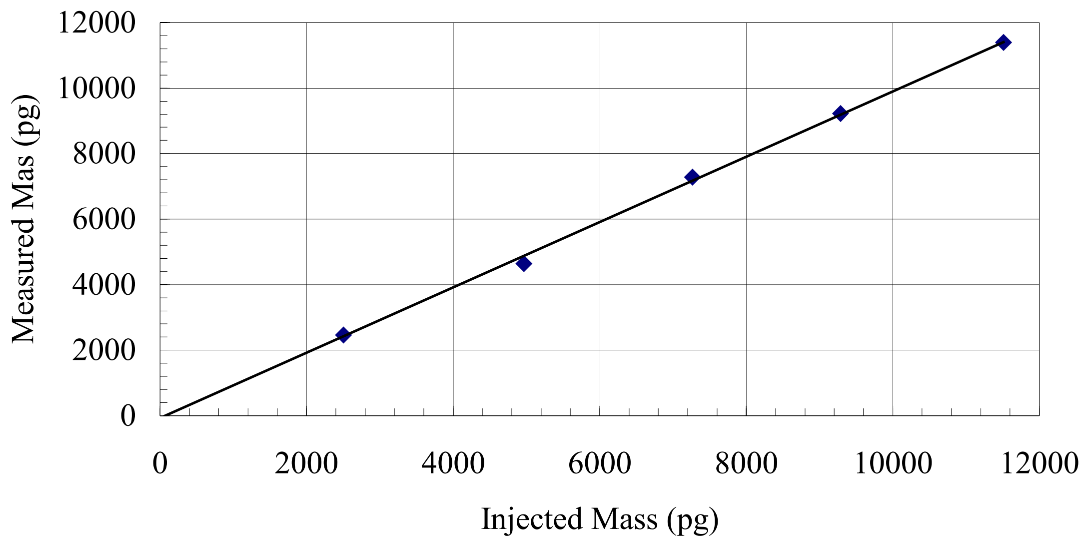


Figure 23: Results of injecting elemental mercury directly on the remote trap. R^2 = 0.9992, y-intercept = -68, slope = 0.99

the results of a spike test where know quantities of elemental mercury were directly injected into the remote trap. The test showed >99% recovery of the elemental mercury injected onto the trap was recovered. Testing was also done where elemental mercury was sent through the entire sample train for the batch sampling method with both the elemental and total mercury impinger chemistry. Figure 24 and Figure 25 show representative recoveries of elemental mercury from the elemental and total mercury reagent impingers. The recoveries were 92 and 88% respectively for the elemental and total impingers.

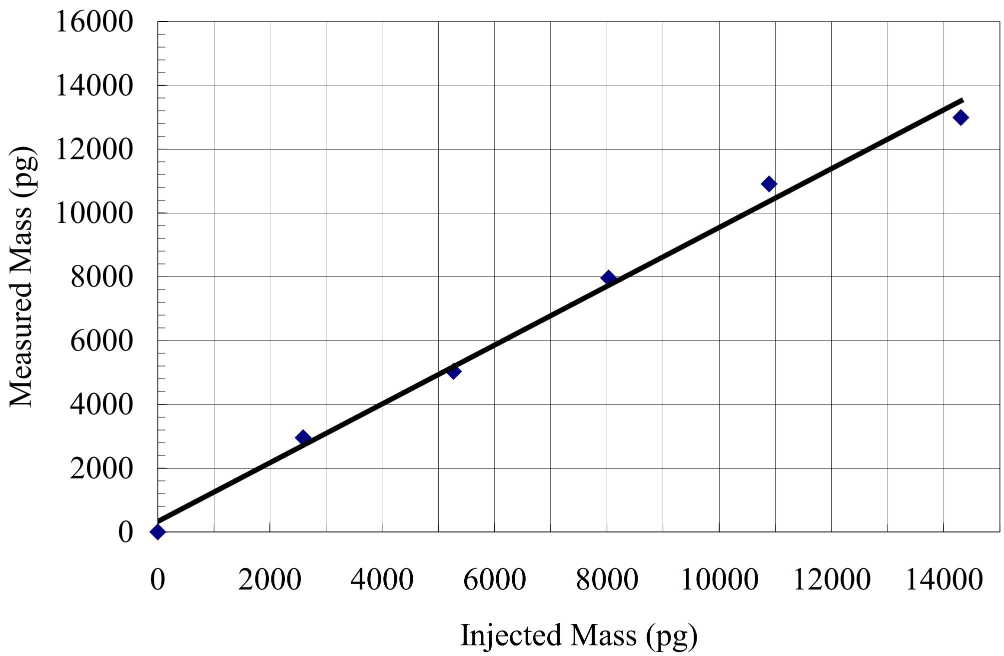


Figure 24: Results of injecting elemental mercury onto the remote trap through the elemental mercury sample train. R^2 = 0.9932, y-intercept = 330, slope = 0.92

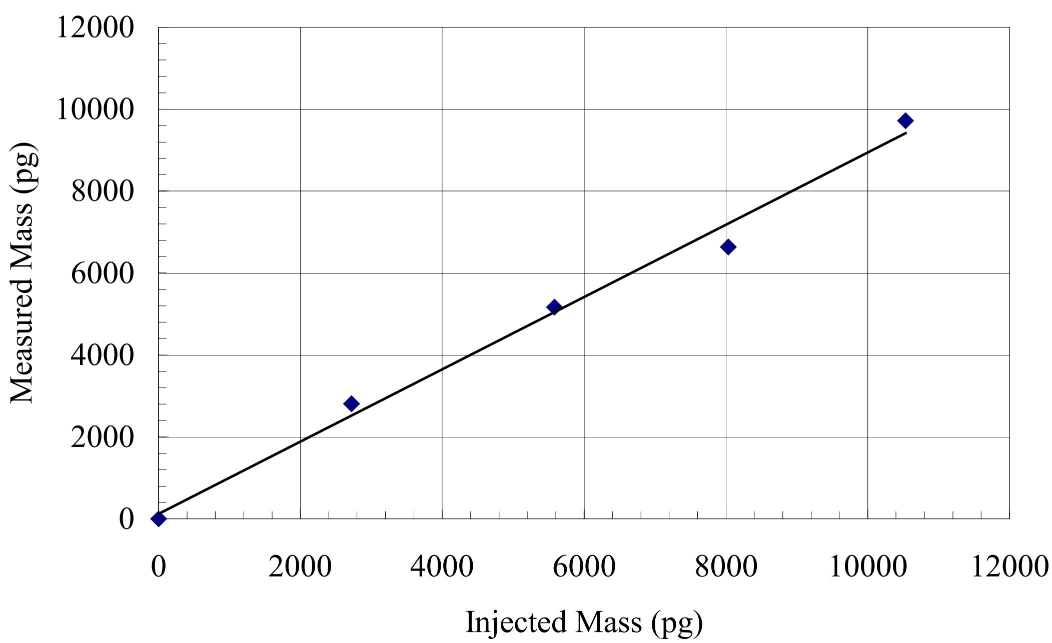


Figure 25: Results of injecting elemental mercury onto the remote trap through the total mercury sample train. R^2 = 0.9902, y-intercept = 128, slope = 0.88

Being able to quantify a mercury spike is a capability not provided for in the PS Analytical system used in this project. It increases the reliability of acquired data by verifying the system integrity. By being able to verify the batch system quantitatively, the comparison between the PS Analytical instruments and the batch sampling becomes an important part of the QA/QC activities for the Hg SCEMS.

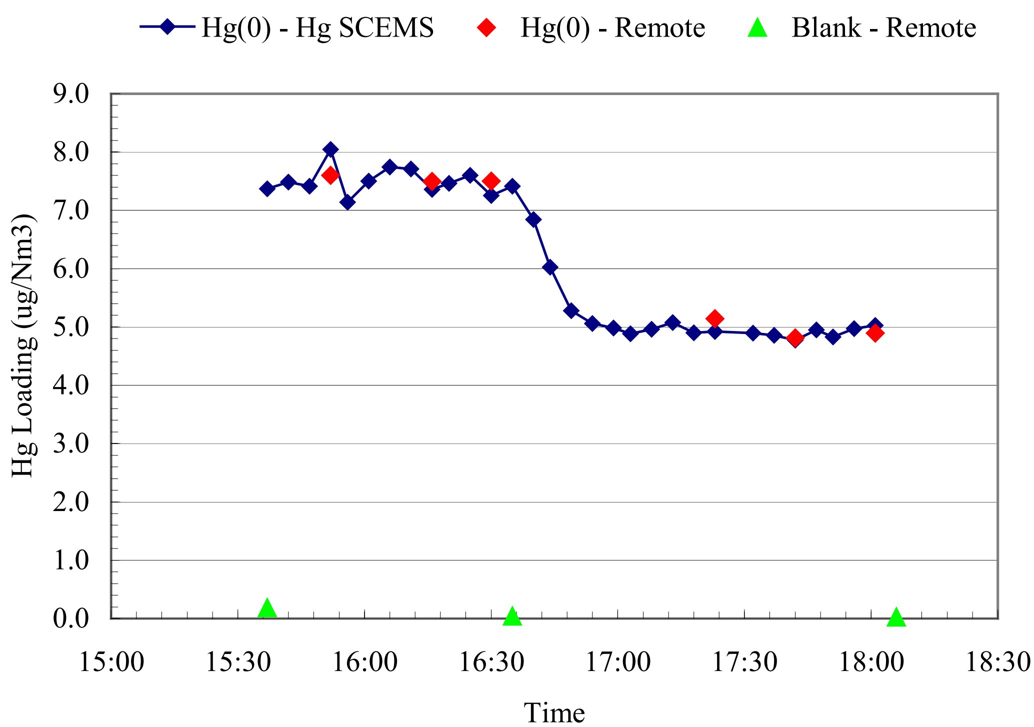


Figure 26: Results of the batch testing method compared to the results obtained with the PSA Hg CEM.

The QSIS probe and Baldwin Environmental probes were modified to be able to run CAVkit gas to the PSA Hg SCEMS and the batch sampling system simultaneously. This allows the sample bias to be verified on both systems and to verify consistent concentrations of elemental Hg for both systems to increase the confidence in the data being obtained by the PS Analytical instruments. Blanks were also run on the remote sample trap by disconnecting the impinger train and pulling zero air through the sample train. The results of this testing are presented in Figure 26. The testing clearly shows that remote trap sampling can be a tool to validate data being collected with the PS Analytical instruments. However, it is quite difficult to keep the remote sample system free of contamination and requires frequent maintenance to obtain reliable data. The measurements are useful for periodic validation of the Hg SCEMS data but not for parametric testing of ECO components.

6.0 Elemental Mercury Addition

The typical mercury concentrations in the flue gas at FirstEnergy's R.E. Burger Power Plant contains a low percentage of its total mercury emissions as elemental Hg. Table 4 lists the results from Ontario Hydro Testing of the flue gas at the inlet of the ECO process. The results show the elemental Hg fraction is <3% of the total mercury in the flue gas stream.

To effectively demonstrate the ECO Process, it was necessary to artificially raise the elemental mercury concentration in the flue gas through the addition of elemental mercury. The mercury addition system used is shown in Figure 27 below.

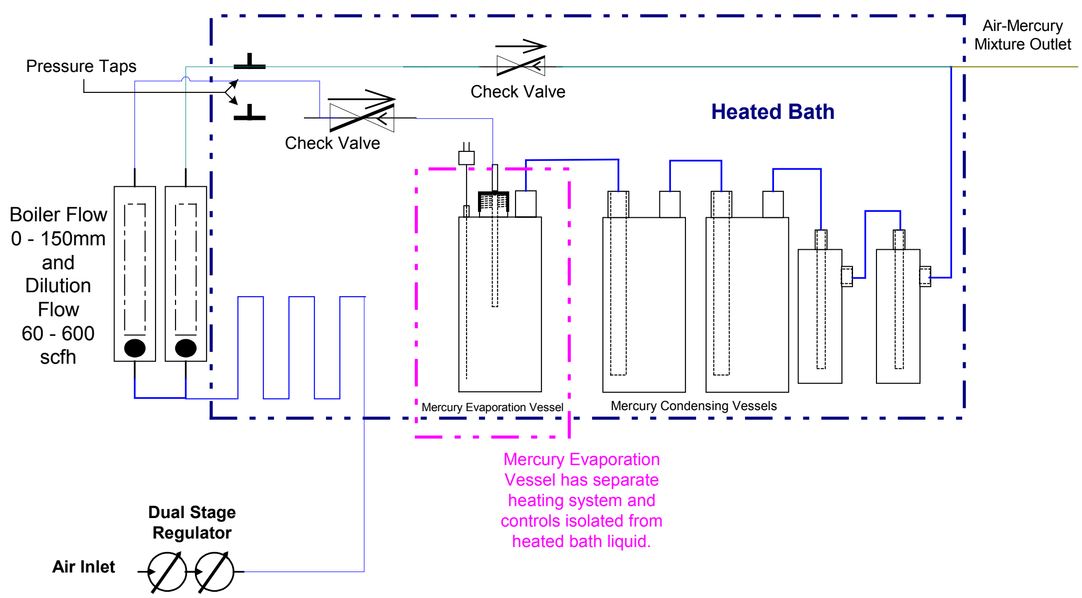


Figure 27: Schematic of the system used to inject elemental mercury into the flue gas.

Elemental mercury is placed inside the mercury evaporation vessel. The vessel temperature is controlled to obtain a mercury vapor pressure above what is required for addition. Zero air is bubbled through the mercury evaporation vessel and becomes nearly saturated with mercury vapor. The Hg laden stream flows through a series of four condensing vessels maintained at a temperature below that of the evaporation vessel. The condensing vessel temperature and gas residence time in the vessels is set such that Hg in the air stream condenses to reach saturated conditions. Dilution air is then added to the saturated mercury stream prior to leaving the temperature controlled environment of the addition system in order to eliminate the need for heat tracing the addition line to the injection point. The temperature of the evaporation and condensing vessels and flow rate of air are adjusted as necessary to give the desired elemental mercury addition rate to the flue gas stream.

7.0 Instrumentation Troubleshooting

Through extensive operation of the PS Analytical instrumentation, several items have been found to be problematic for operation and require continuous attention to be able to obtain high quality data. It took extensive efforts of operation and troubleshooting of the PS Analytical Hg SCEMS to develop the protocols discussed in the previous sections for obtaining quality data. The effort has developed a body of knowledge to increase the amount of time the PS Analytical instruments can run and obtain quality data.

Several significant problems associated with measuring mercury in the flue gas stream were revealed during testing on actual flue gas. These problems can be broken into three types: (i) Hg speciation module, (ii) sample gas extraction, and (iii) hardware failures. Each of these three areas of concern and the steps taken to address these issues is discussed below.

7.1 Hg Speciation Module Troubleshooting

The Hg Speciation Module is an integral part of the measurement system. Its operation is essential to determine the fraction of elemental and oxidized mercury in the gas phase of the flue gas stream. During operation, many problems were addressed to be able to operate the speciation module to obtain quality data without damaging equipment. These problems which are discussed below are: (i) sample flow control, (ii) acid gas removal, (iii) moisture removal, (iv) impinger precipitates, (v) reagent contamination, (vi) reagent refresh rates, and (vii) hardware failures.

7.1.1 Sample Flow Control

The Galahad instruments require flow rates of ~½ L/min. Since the sample line is a vented stream, an excess of flow must be sent to the analyzer to avoid diluting the sample stream by pulling air in through the vent. Therefore, 2 L/min of sample flow is sent through each sample stream in the Hg speciation module to the instrument rack. Maintaining this flow has been problematic for the total Hg channel. There were frequent two problems.

The first problem was that the concentrated NaOH solution would precipitate and crystallize in the reagent impinger where the reagent first meets the flue gas. The conclusion was that the hot flue gas was causing the NaOH solution to concentrate through evaporation to a point where it would crystallize. To improve the system reliability, and minimize this problem, the impinger was replumbed. The reagent capillary was brought in through the gas exit port, and delivered the NaOH reagent to the bottom of the impinger instead of dripping from the reagent capillary where the hot flue gas was coming in. This modification eliminated NaOH crystallization in the reagent impinger which had been clogging the reagent impingers and changing the sample flow.

The second problem was caused by excessive flue gas flow through the reagent impingers. A black precipitate of tin oxide would form in the total Hg channel waste impingers. Although the mechanism for the precipitate formation is not well understood, its appearance was an indication of excessive flue gas flow through the total mercury channel. As it formed, the tin oxide precipitate would build up in the waste impingers and prevent them from draining properly. The waste impinger would then fill with spent reagent solution and spill fluid onto the water slip detectors triggering an alarm to shut down the sample and reagent pumps. The water slip indicators were also problematic in that they would only trip the pumps on an irregular basis. When the water slip indicators failed to work properly, the NaOH was pumped through the sample train and led to damage of both the stream selector and the Sir Galahad analyzer. Daily maintenance of the water slip alarms is required for reliable operation of the PS Analytical instruments.

In order to provide a simple operator check that the flow delivered by the speciation module to the stream selector in the instrument rack was sufficient, a flowmeter was installed in the excess flow vent line. The flowmeter can be seen in Figure 28.

7.1.2 Acid gas removal

When the Amasil traps are exposed to acid gases they become fouled and unreliable for mercury measurement. During operation of the PS Analytical system, several traps were fouled. Through extensive experience with SO_2 scrubbing, the fouling was attributed to the inability of the elemental channel to capture acid gases due to the low pH of the solution (pH ~3). Therefore, the reagent recipe used in the elemental Hg channel to scrub acid gases was changed. Several grams of NaOH was added to the KCl solution to raise the pH from ~3 to ~7. This is the same approach as for the batch sampling discussed in section 5.0, except the PS Analytical instruments require the use of one impinger instead of two. Results have shown reduced fouling of the Amasil traps as a result of the reagent change.

7.1.3 Moisture Removal

Due to poor efficiency of the condensing impingers water has been observed to condense in the sample lines and in the stream selector which houses the mass flow controller during prolonged use of the Hg SCEMS. Moisture in the sample lines is an operational issue due to the damage that occurs when water is introduced into the stream selector and digital mass flow controller. Once moisture reaches the MFC, the controller needs to be removed from the system and repaired or replaced. Several steps have been taken to improve the moisture removal including (i) reducing the ambient air temperature in the speciation module, (ii) altering impinger flow, and (iii) installation of drip legs for moisture removal.

The ambient air temperature of the Hg speciation unit was decreased. By doing so the reagent impinger temperature decreases, decreasing the saturation water vapor pressure in the impingers. The lower the water vapor pressure the less moisture sent to the Peltier cooler for removal. The decreased loading improved operation of the Peltier cooler.

The flow through the impinger was minimized as much as possible to maximize the retention time of the sample gas in the Peltier cooler. The longer retention time improved the cooler's ability to remove water.

The final modification made to eliminate condensation in the sample lines was to add a drip leg prior to the sample entering the stream selector. The drip legs shown in Figure 28 are drained periodically and prevent moisture that condenses in the sample line from building up and damaging the MFC.

Figure 28: Picture of excess flow meter and drip legs added to instrument rack to prevent moisture from condensing and damaging MFC.

7.1.4 Reagent Contamination

The environment at a coal-burning power plant introduces a certain level of difficulty in making low-level mercury measurements due to the high levels of ash in the air. This particulate matter can contaminate not only sampling surfaces, but also the reagents used in the conditioning/speciation units. There are two levels of care required with reagents used to make low-level mercury measurements, (i) reagent purity and (ii) reagent contamination.

Reagent purity is easily addressed as discussed in section 4.3. However, maintaining the required level of cleanliness in a power plant environment required additional protocols. Due to the quantity required for continuous operation of the Hg SCEM reagents were mixed on site to minimize their cost. The water used for mixing reagent solutions, washing, and rinsing the reagent containers after each use is boxed 18 MΩ de-ionized water purchased from Ricca Chemical Company. In addition to using good laboratory practices for reagent preparation, each batch of reagents was sparged with argon or nitrogen to drive off any residual elemental mercury. Additionally, the reagent containers were sealed during operation to allow only the reagent capillary and a small vent to cross the sealed cap. Checks for contamination were made by running frequent blank on the Hg SCEMS.

7.1.5 Reagent Refresh Rate

The reagent refresh rate effects speciation of Hg in the unit. The peristaltic tubes feeding reagents to the impingers and removing waste from condensers have a lifetime of three days. As the tubes become worn and inelastic, the refresh rates of the reagents become inadequate and the removal of waste reagents becomes too low. The refresh rates for the reagents in the total mercury channel have been optimized to 3.5 mL/min. If the refresh rate of the NaOH/$SnCl_2$ reagent drops below this, the stannous chloride becomes depleted, and the reagent becomes ineffective in reducing oxidized mercury. One of the first indications that the flow of NaOH/$SnCl_2$ has been interrupted is that the total mercury concentration is the same as the elemental mercury concentration. This behavior is observed ~20 minutes after the NaOH/$SnCl_2$ reagent is interrupted. The reagent delivery can be interrupted by any number of mechanisms, the most frequent of which were peristaltic pump tube failures and clogged capillaries. Increasing the NaOH/$SnCl_2$ addition rate to 5 mL/min did not seem to affect the total mercury measurements however, so 3.5 mL was chosen to minimize the cost of operating the instrument, but provide for adequate oxidized mercury reduction in the total mercury sampling channel. The refresh rates for the reagents in the elemental mercury channel have been optimized to 2 mL/min. Tests were conducted in which the KCl reagent delivery rate was increased to 4 mL/min from 1 mL/min, with no subsequent effect on the elemental mercury measurements. It was thought however, that a KCl reagent addition rate less that 2 mL/min would affect the ability of the reagent to scrub out acid gases leading to failure of the Amasil trap in the Sir Galahad mercury analyzer.

7.2 Sample Extraction

Testing in an environment with high ash loading has led to (i) difficulties extracting an ash-free sample from the inlet sampling location and (ii) oxidation of elemental mercury with reactive ash. The problem of ash contamination in the gas phase measurements can be seen in the total mercury concentration values recorded with zero-air fed to a Baldwin Environmental probe.

Figure 29 presents results of mercury measurements made on zero air with the probe after using the probe to sample inlet flue gas for several hours. While sampling flue gas the probe's filter had been blown back with compressed air after each sample in an effort to remove accumulated ash.

The high blank values (>100 $\mu g/Nm^3$) seen in Figure 29 are evidence of ash contamination in the sampling system. As a check, the system used to acquire the data shown in Figure 29 was cleaned and the blank measurements repeated. The cleaning process included cleaning of the sample lines and sample pump head with a 10% nitric acid solution followed by several rinses with de-ionized water. Figure 30 presents the results of mercury measurements made on zero air with the cleaned probe.

The cause of the ash contamination of the sample lines and pump head was due to deformation of the Teflon filters supplied with the Baldwin Environmental sample probes. The deformation allowed ash to slip past the filters due to gaps that formed

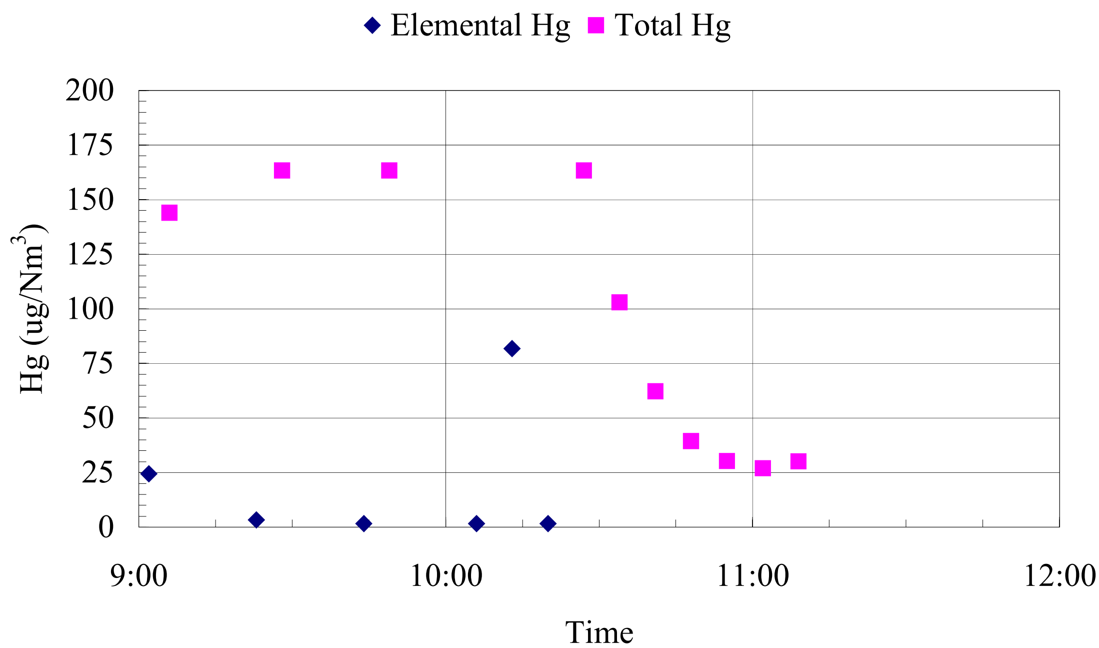


Figure 29: Zero-air sent to ash contaminated sample probe

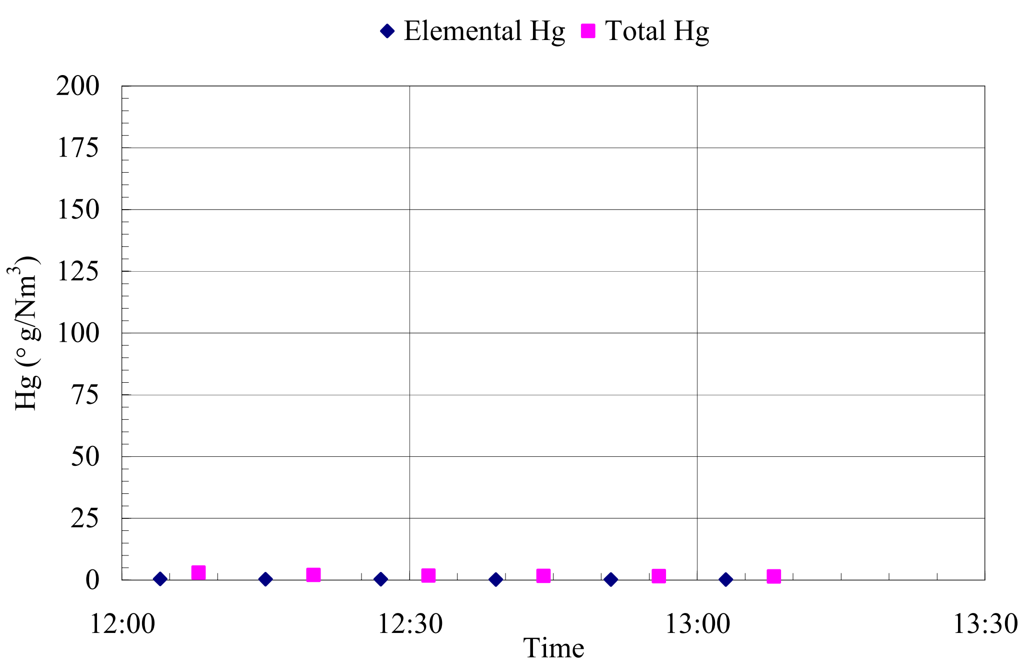


Figure 30: Zero air sent to clean probe

between the filter and filter housing. Once the ash was past the filter, it could be captured in the impingers where the particulate phase mercury was digested, released, and measured as gas phase mercury. When measured by the PSA instruments, it is seen as large spikes in the total Hg measurement. Since the reagent impinger for the elemental mercury channel does not contain concentrated NaOH, it was not affected by the ash contamination.

To address the filter deformation issue, ceramic and sintered metal filters were installed and tested. Although the ceramic and sintered metal filters could stop the deformation and ash bypass problem, oxidation of Hg^0 to Hg^{2+} by reactive ash was still being observed with the Baldwin Environmental sample probe. This problem was caused by insufficient ash removal by the filter blowback feature. Figure 31 shows the decrease in elemental mercury as a function of time with the blowback feature turned off. However, the oxidized mercury concentration does not

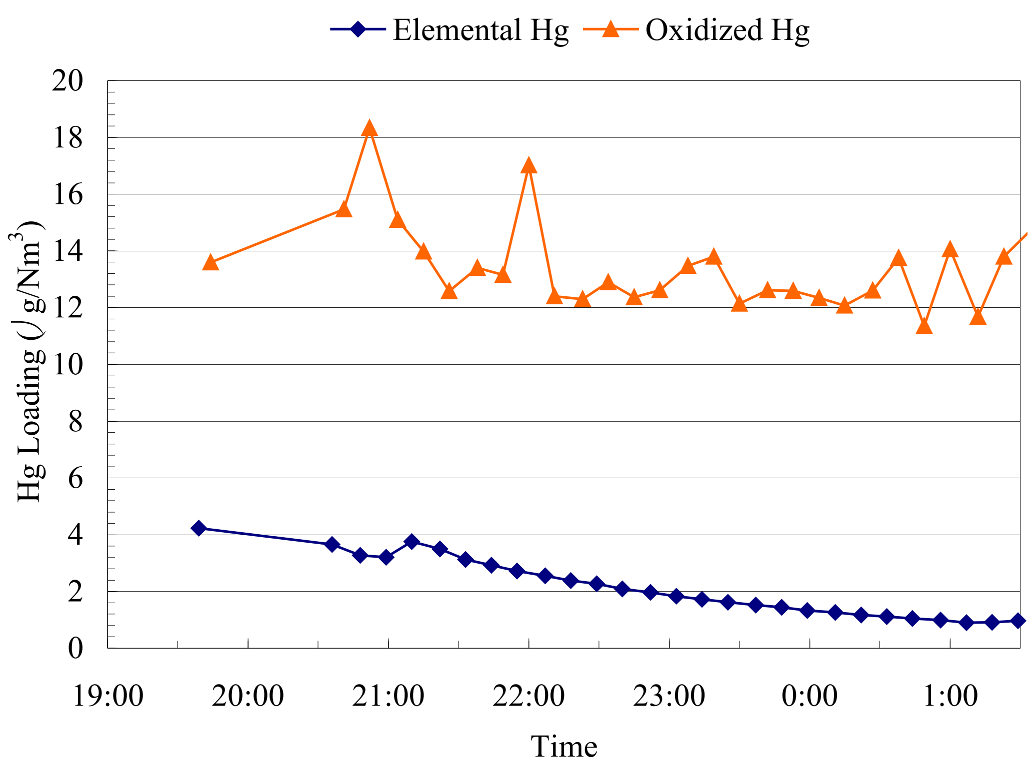


Figure 31: The elemental mercury decreases with time with the blowback feature disabled.

increase as expected. It is possible that the mechanism for mercury oxidation with reactive ash leaves the mercury bound to the particulate matter. Therefore, the speciation and the quantification of mercury are compromised with the Baldwin Environmental probe filter system.

Through discussion with Sharon Sjostrom of EMC Engineering, it was decided the installation of the Apogee Scientific QSIS probe could decrease or eliminate the effects of ash the mercury measurements. A QSIS probe was installed on the inlet sample port of the pilot unit. Only one QSIS probe was required because the ash loading on the outlet of the system was several orders of magnitude less than on the inlet. Initial results (Figure 32) showed only 1.6% of the elemental mercury was oxidized across the clean QSIS filter.

However, within days of continuous use, the QSIS filter on the inlet sampling port started oxidizing elemental mercury.

Figure **33** shows the oxidation of elemental mercury after several days of use. After using the filter for approximately 80 hours to sample flue gas at the ECO inlet, a CAVkit test showed 25% of the elemental mercury was being converted to oxidized mercury across the QSIS filter. Apogee Scientific suggested protocols for cleaning the QSIS filter. These protocols were initially successful in keeping the oxidation of elemental mercury across this filter to a minimum. However, their effectiveness decreased over time and eventually became ineffective. After this point, an unacceptable amount of elemental mercury oxidation across the QSIS filter was always observed to occur. The amount of oxidation was measured to be as high as 60%.

In addition to the gradual degradation in performance seen with normal use, boiler upsets deposited material on the probe which required immediate cleaning of the sintered metal filter.

As a result of the continuous problems encountered with speciated mercury measurement in the inlet flue gas, Powerspan installed new ductwork to supply flue gas to the ECO pilot unit from outlet of the Burger Plant's dry ESP. In this installation, the pilot's cyclone separator was bypassed and the pilot dry ESP taken out of service. The new duct configuration supplied flue gas with a "normal" ash content, that is an ash content representative of that expected in commercial ECO installations. Drawing flue

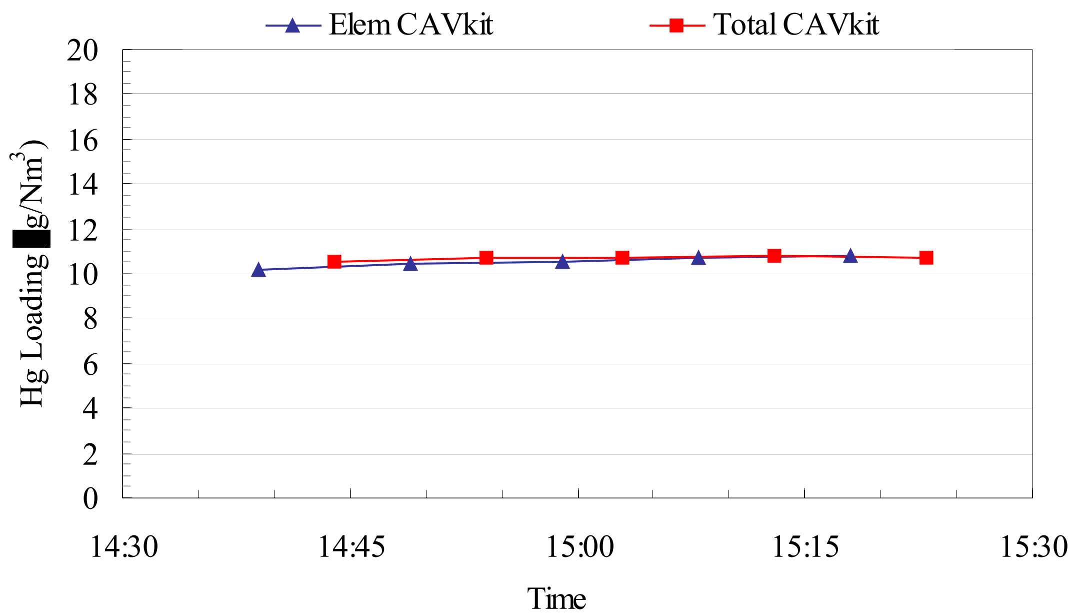


Figure 32: CAVkit results run on a clean QSIS filter.

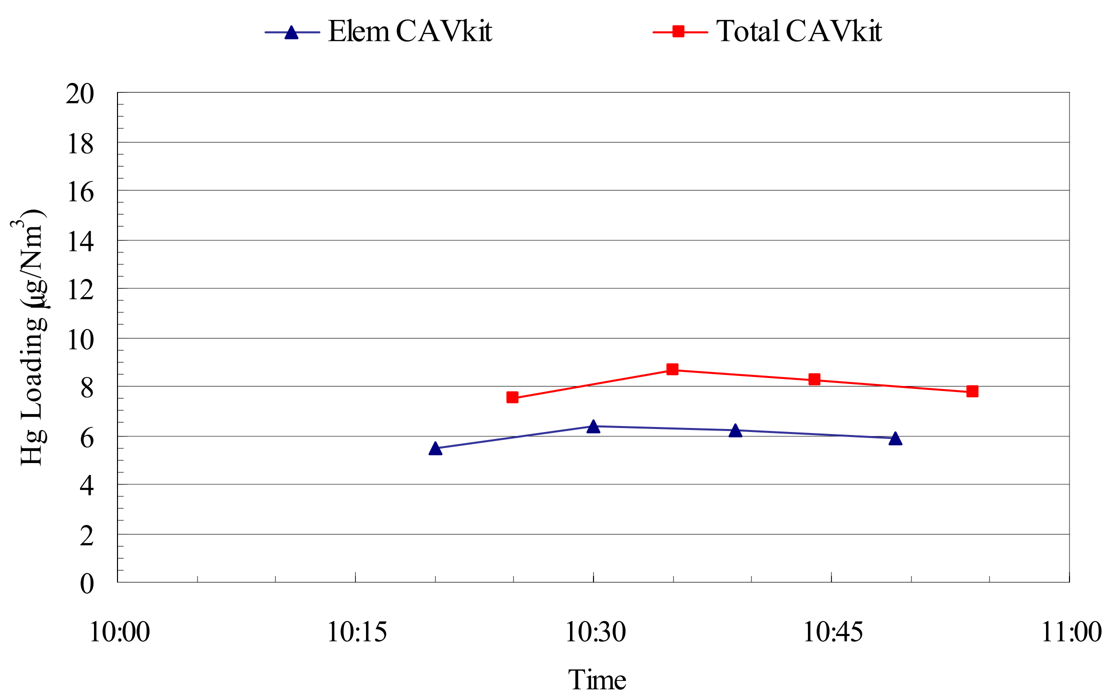


Figure 33: CAVkit results run on a QSIS filter after ~80 hours of use.

gas from the outlet of the plant's ESP reduced the ash loading at the inlet by a factor of 10 over that measured with flue gas supplied from the ESP inlet and using the pilot's ash removal equipment. The normal ash loading and numerous protocols developed for sampling allowed for improved measurement of mercury.

7.3 Hardware Failures

In addition to the problems associated with sampling and reactive ash, frequent and numerous hardware and electronic component failures also occurred in the PS Analytical Hg SCEMS instruments. The list of failed components is extensive. It includes the Baldwin environmental and QSIS sample probes, the Hg speciation modules, and instrument rack equipment. The Baldwin Environmental sample probe components that have failed and required replacement were circuit boards, thermocouples, pumps, diaphragms, filters, blowback solenoids, fans, and heaters. The QSIS probe also experience several hardware failures that included cracked filters and jammed impellers in the Gast blower. In the Hg speciation unit, the failed components included circuit boards, power supplies, temperature controllers, heaters, Peltier coolers, impingers, solenoids, peristaltic pump motors, circuit breakers, valves, and water slip detectors. Finally, failures in the instrument rack included pressure regulators, relay boards, mercury lamps, valves, and control cables. The failure of these components demonstrated that the PS Analytical instrumentation was not yet ready for field operation on a twenty-four hour, seven day a week basis. Rather, the instruments could operate well for 6 to 8 hours a day with constant monitoring.

8.0 Mercury Measurement in Ash and Process Fluid

Developing a method to measure mercury in process liquid solutions and in captured particulate matter was necessary in order to track mercury throughout the ECO process. The particulate matter analysis was straight forward, and the Modified ASTM Method D 6414-01 was verified for our system. The ECO process fluid proved to cause problems for the EPA Method 254.1 mercury analysis. Therefore, it was necessary to develop a new digestion procedure that would not interfere with the mercury measurement by cold vapor atomic absorption. The following is a discussion of the verification of the methods used to measure both liquid phase and particulate mercury in the ECO process.

8.1 Particulate Mercury Analysis (Mercury in Coal Fly Ash)

The method used to measure particulate mercury is the Modified ASTM Method D 6414-01, “Standard Test Method for Total Mercury in Coal and Coal Combustion Residues by Acid Extraction or Wet Oxidation/Cold Vapor Atomic Absorption”. To verify the method a Standard Reference Material (SRM) 1633b, “Constituent Elements in Coal Fly Ash,” was digested and analyzed.

Two samples of the SRM were digested and analyzed by cold vapor atomic absorption and compared to the certified value for mercury in the SRM. The results of the analysis are listed below in Table 5.

Sample	Concentration	Percent Recovery
SRM Hg Concentration	141 ± 19 ppb	------
SRM 1633b-1	161 ppb	114%
SRM 1633b-2	157 ppb	111%

Table 5: Results of SRM Analysis of Particulate Hg

The results of the verification show a mean (95% Confidence) of 159 ± 25 ppb. The method is an acceptable means to measure the particulate mercury in the ECO process.

8.2 Mercury Analysis in Process Fluids

The Modified EPA Method 245.1, “Determination of Mercury in Water by Cold Vapor Atomic Absorption Spectrometry”, has been modified to measure mercury in the ECO process fluids. The method has been modified due to interferences created by the digestion of ECO process fluids and the subsequent analysis by cold vapor atomic absorption. Rather than a mixture of acids, only concentrated nitric acid is used to digest ECO process fluids.

Testing was done to investigate the reliability and reproducibility of the method with the modified digestion to perform mercury analysis in liquids. Duplicate samples were prepared by adding 5 mL of the test solution to 20 mL of ultra-pure concentrated (69%) nitric acid (JT Baker Ultrex Grade) in a BOD bottle. To one of the samples a known quantity of mercury standard solution (0.1 μg Hg/mL) was added. The BOD bottle was covered with foil and digested for 2 hours in a hot water bath at 90 to 95 °C. After 2 hours, it was removed from the hot water bath, cooled to room temperature, and diluted to volume with deionized water. Five milliliters of stannous chloride were added to the sample solution and it was sparged for analysis. Analysis is done using a Buck Model 400 A Mercury Analyzer. A schematic of the analysis train is shown in Figure 34.

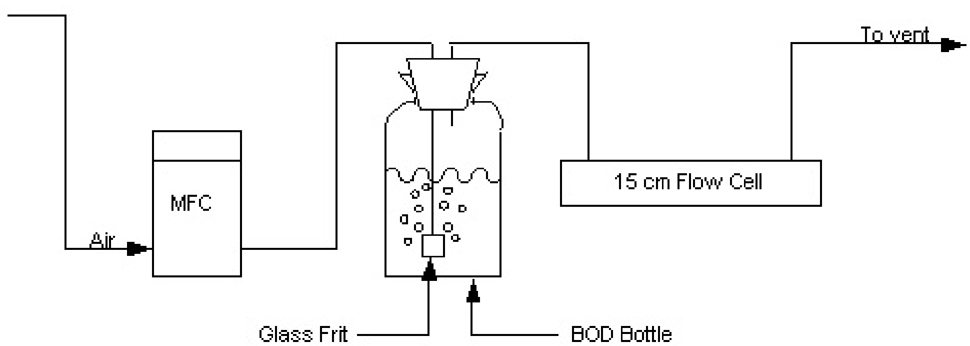


Figure 34: Schematic of the train used for mercury analysis of liquids obtained from the ECO scrubber.

Testing was performed both on synthetic solutions and on process fluid samples drawn from Burger ECO pilot. For each test, duplicate solutions were analyzed; one was analyzed unmodified and the second was spiked with a known quantity of mercury. The results of this testing is shown in Table 6. The test shows that the digestion process developed for the ECO process fluids does not interfere with the measurement of mercury by cold vapor atomic absorption. The test solution compositions are proprietary, however solution 1 contains only the component from the ECO process fluid that required the modification of the EPA method 245.1 digestion. Solution 2 contains the ‘problem’ component as well as the other major components in the process fluids.

	Expected Hg Concentration (μg)	Analyzed Hg Concentration (μg)	Percent Error
Solution 1-1a	0.00	0.00	0
Solution 1-1b	0.40	0.27	-32.3
Solution 1-2a	0.00	0.00	N/A
Solution 1-2b	0.15	0.20	-22.8
Solution 2-1a	0.00	0.00	0
Solution 2-1b	0.40	0.46	14.1
Solution 2-2a	0.00	0.03	N/A
Solution 2-2b	0.40	0.47	16.9
Burger Plant Solution-1	N/A	0.21	N/A
Burger Plant Solution-2 (Spike)	N/A	0.375 (Spiked with 0.15 μg Hg) Delta = 0.375-0.211 = 0.164 μg	9.3

Table 6: Results of Digestion Verification

It has been concluded from the data that the results are consistent with error values obtained in EPA Method 245.1. At a known mass of 0.41 μg of mercury, the method reports a standard deviation of 0.112 μg of mercury, which corresponds to a range of 0.522 μg to 0.298 μg and an error of ± 27.3%. At a know concentration of 0.06 μg of mercury the method reports a standard deviation of 0.039 μg of mercury, which corresponds to a range of 0.099 to 0.021 μg and a resulting error of ± 65%.

8.3 Instrument Precision Testing

Analysis on five identically prepared samples was done to test the precision of the Buck Analyzer. The samples were prepared by adding the same quantity of mercury standard to 20 mL of digestion solution in a BOD bottle. An aliquot of Solution 2 was then added to each of the bottles. The bottles were digested, diluted to volume and analyzed for mercury content. The results of the test are shown in Table 7. The statistical analysis shows a standard deviation of 0.0006 μg Hg, with an average value of 0.057 μg. The percent relative standard deviation is 1.1 % and the mean (95% confidence) was 0.575 ± 0.007. The conclusion of this testing is that the Buck Analyzer is providing reliable and reproducible measurements

	Concentration (μg Hg)
Sample 1	0.566
Sample 2	0.580
Sample 3	0.573
Sample 4	0.580
Sample 5	0.575

Table 7: Results from Instrument Precision Testing

8.4 Instrument Linearity Testing

The final verification done of the mercury measurements for the ECO process was a linearity check of the instrument. Seven solutions were prepared for analysis by adding known amounts of mercury to them. The solutions were digested by the method verified above and analyzed. The results are shown in Table 8 and Figure 35. The figure includes the 95% confidence intervals for the measurements. This test shows the Buck Analyzer responds linearly from 0.04 to 0.6 μg of mercury.

Solution	Mercury Mass (μg)	Absorbance
1	0.04	0.009
2	0.06	0.015
3	0.08	0.022
4	0.15	0.038
5	0.25	0.063
6	0.40	0.102
7	0.60	0.149

Table 8: Results from Instrument Linearity Check

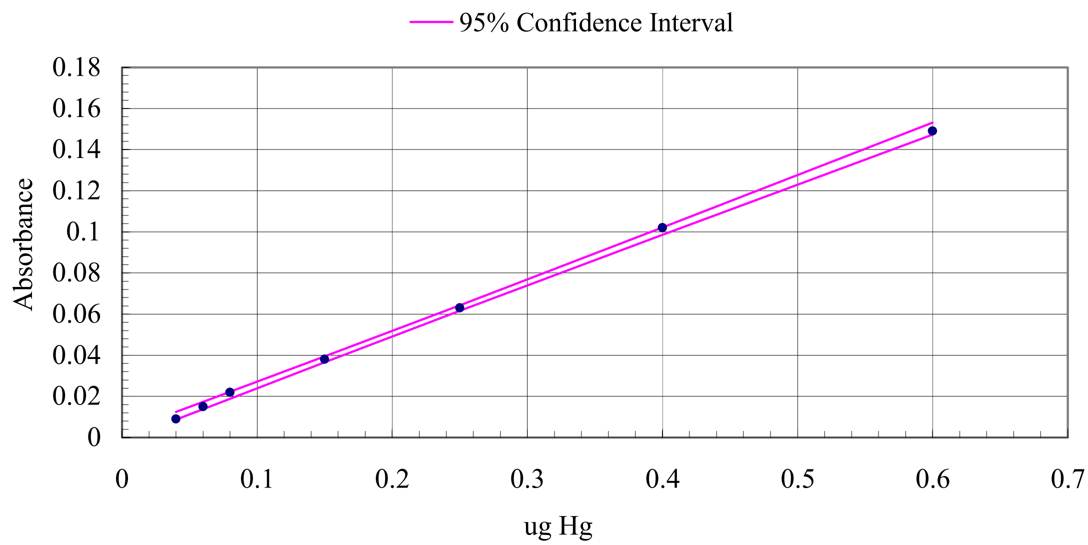


Figure 35: Mercury analyzer linearity check with 95% confidence intervals. Statistical analysis: $R^2 = 0.9994$, y- intercept = 0.0006, and slope = 0.2494

9.0 Conclusion

A system for sampling gas phase mercury in the flue gas of the ECO pilot at FirstEnergy's Burger Power Plant was selected, installed and operated to support testing of mercury removal in a multi-pollutant control technology. The system chosen was provided by PS Analytical and included sample probes, sample conditioners, a stream selector and an atomic florescence spectrometer. The PS Analytical equipment performed well in the clean flue gas environment at the outlet of the ECO process. However, the ash loading at the inlet of the ECO system, and the ability of the ash to oxidize elemental mercury, proved problematic for accurately determining the concentrations of elemental and oxidized mercury in the flue gas. Extensive efforts to improve the inlet flue gas measurements included testing of multiple sample filters, changing sample probe operating conditions, consulting with industry experts, installation and testing of inertial separation based sampling systems, and installation of ductwork in order to provide flue gas with a reduced ash loading to the ECO pilot . None of these efforts were successful at providing a system and conditions where routine and accurate measurement of the mercury species contained in the flue gas entering the pilot could be made.

The inability to accurately measure gas phase mercury species in the inlet gas substantially restricted the investigation of elemental mercury oxidation by the ECO process' barrier discharge reactor. In order to provide a measure of the inlet elemental mercury concentration, measurements were made at the outlet of the ECO process with the barrier discharge reactor secured. Testing in this manner did not allow sufficient time for the entire ECO process to reach a steady state, restricting the parametric investigation to operation of the barrier discharge reactor. Planned parametric testing of the ammonia scrubber and wet electrostatic precipitator could not be accomplished.

Protocols were developed throughout the testing for calibration, maintenance, troubleshooting and repair of the installed gas phase mercury monitoring system. Operating procedures were also developed, including frequent checks by the ECO pilot operators. Frequent monitoring and maintenance were found to be required in order to keep the instrumentation operating for more than a few hours at any one time. Two complete measurement systems were installed at the ECO pilot, with the ability to sample from four locations in the process. However, the extensive efforts required to keep the measurement systems operating restricted sampling to two locations at any one time.

In addition to gas phase mercury measurements, methods were adapted and tested for measurement of mercury in ECO process fluids. The measurement of mercury in captured ash was done using a standard method with modification. Mercury measurement in the ECO scrubber fluids required modification of standard methods to eliminate matrix effects in the mercury digestion process. The modified method was successfully tested and used in the project.

10.0 References

[1] Brown, Smith, Hargis, and O'Dowd, *Mercury Measurement and its Control: What We Know, Have Learned, and Need to Further Investigate*, J. Air & Waste Manage. Assoc, 49, 628 – 640.

[2] *Self-Evaluation Engineering Study Test Report,* prepared by Air Compliance Testing, Inc., December 6, 2002

10.0 List of Acronyms

ASN – Ammonium Sulfur Nitrates
CAVkit – Calibration Verification
SCEMS – Semi-Continuous Emission Monitoring System
DBD – Dielectric Barrier Discharge
ECO – Electrolytic Catalytic Oxidation
ESP – Electrostatic Precipitator
QAQC – Quality Assurance Quality Control
QSIS – Quick Silver Inertial Separator
TVM – Total Vapor phase Mercury
WESP – Wet Electrostatic Precipitator

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Appendix A: Hg SCEMS Operating Manual

A.1 **Preparation of Reagents**

To prepare 10 liters of KCL reagent:

1. 10% (w/v) KCl (Potassium Chloride) for the Hg^0 Channel
   i. Rinse out the reagent container and cap with deionised water

   ii. Dissolve 1000 grams of KCl (Potassium Chloride) in 10 liters of deionised water.

   iii. Stir until the KCl (Potassium Chloride) is fully dissolved.

   iv. Add 100 grams NaOH pellets to the solution and stir until dissolved. (This helps scrub acid gases from the flue gas samples sent to the analyzer.)

To prepare 10 liters of NaOH/SnCl2 reagent:

If using the 25% NaOH prepared solution (premixed) from VWR use the following steps to make **10 liters** of NaOH / SnCl2 reagent:

i. Rinse out the reagent container and cap with deionised water

ii. Pour 6.3 liters of the 25% (w/w) into the reagent container. (The 6.3 liter level on the container is marked in red sharpie)

iii. In a separate container, put 200 grams of $SnCl_2$ into 1/2 liter of water. Mix to form white slurry. Shake the solution vigorously for 5 minutes.

iv. **Slowly** pour a small amount of the $SnCl_2$ slurry into the NaOH solution. The stannous chloride will immediately precipitate out. Stir the solution until it dissolves. Keep adding / dissolving until all the slurry is gone.

v. Slowly add DI water to the NaOH solution to bring the solution level to 10 liters.

Note: Make sure to use only NaOH containers for the NaOH reagent and KCl containers for the KCl reagent. The containers are labeled.

Note: The capillary wands inserted into the reagent containers are color-coded: red for NaOH and white / clear for KCl.

A.2 Startup Procedure

Before operating the Hg CEMs: (i) the lines need to be cleared of any condensed moisture, (ii) the needed gases (instrument air, blowback air and argon) must be available, (iii) the conditioners and sample probes must be prepared and warmed to operating temperature, (iv) the instruments in the rack prepared for operation. (This includes warming up the CAVkit unit, starting the mass flow controller and calibrating the Sir Galahad analyzer.)

A.2.1 Lines

1. In each of the conditioning boxes, remove the sample lines (leading to the CEMs trailer) from the **top** of the water slip indicators.

2. Wrap the end of the sample lines in a clean paper wipe-all to catch any condensed moisture in the lines while they are being blown back.

3. In the CEMs trailer, unhook the Hg elemental and Hg total lines for both the inlet and outlet for each instrument rack.

4. Gently blow zero air back through each sample line for approximately two minutes.

5. Reconnect the sample lines to the correct ports on the instrument racks.

The reason for this blowback is to avoid sucking any condensed water in the sample lines into the instruments and mass flow controller. It has happened twice already and is very expensive to repair.

A.2.2 Gases

1. Turn on the argon gas cylinder (located behind the CEMs trailer). The pressure should be set at ~35 psi.

2. Turn on the blowback air. The pressure of the blowback regulator should be set to ~90 psi. (The air source / filters / regulator are located on the wall behind the outlet sample probe.)

3. Turn on the air for the zero-air generator (located in the CEMs trailer by the plant air source). The pressure on the zero-air regulator should be set at ~50 psi.

A.2.3 Preconditioning units and Sample Probes

Note: *Any time you are working inside the conditioner, please wear safety glasses and latex / rubber gloves for your protection and to avoid contamination!*

1 Ensure that sufficient reagents have been prepared (approximately 1 liter per day per conditioner for KCl and 5 liters per day for NaOH / $SnCl_2$).

2 Click peristaltic pump cassettes down and to tension ratchets ~45^o from horizontal. (The pump tubes should be fairly new / fresh as well. Aged tubes do not work very well in these conditioning boxes!) [See peristaltic pumps section for correct color-coding of the tubes.]

3 Plug in the conditioning unit to the proper outlet. (The conditioners and sample probes have their own circuits that are labeled.)

4 Open the rear of the Preconditioning unit to gain access to the orange power switches.

5 With the mains power on, turn all the orange switches to the "on" position so that they light up, **except** the switch marked "Pumps". The "Override" switches should all be in the "down" position.

6 Allow the Heated Line and Hot Box Controller temperatures to reach 400^{o}F and the Channel 1 and Channel 2 Peltier coolers to reach 4.5^{o}C. (Note: These values are pre-set on the controllers and should not need to be adjusted). (Note: if the cooler switch is off, the heated lines and hotbox are also off – even if the switches are in the "on" position.)

7 Plug in the sample probe filter hotboxes and allow ~60 minutes for them to reach temperature.

8 If the Apogee Scientific QSIS filter is to be used, the filter heater and jacket heater need to be powered up. Once the recommended temperatures have been reached, turn on the Gast blower and open the QSIS filter isolation ball valves to start flowing flue gas through the racetrack.

9 While the probes, lines and hotboxes are heating, check each water slip indicator for functionality in all conditioners being used. To check the detector, remove the bottom of the slip detector from its receptacle and close the contact with a clean conductor. The slip alarms and relays will then activate. At the conclusion of the test, restore the detector to its normal operating position.

10 The old NaOH reagent (if any) should be emptied out of the NaOH impinger. Please be careful in removing these impingers. They are fragile and expensive!

11 Once all operating temperatures are correct, the conditioners should be prepared for operation in the following order: (i) connect the Teflon "T" to the top of the NaOH reagent impinger, (ii) connect the Hg^T sample line to the top of the water slip indicator, (iii) connect the Teflon "T" to the top of the KCl impinger, (iv) connect the Hg^T sample line to the top of the water slip indicator. Watch carefully for overflow and drawbacks at each step. In the past there have been large amounts of reagents "sucked" into the heated sample lines and large amounts of reagents spilled in the conditioners.

12 Open the rear of the Preconditioning unit and switch on the "Pumps" switch. At this stage the Peristaltic pump and the Filter box pump will start up, delivering reagents and sample gas to the impingers.

13 Observe the conditioning/speciation units to observe correct reagent flow to the impingers and correct gas flow through the impingers.

Note: Do not let the pumps run for more that 20 minutes without a blowback. This may mean shutting the pumps off during troubleshooting and calibrations. Without blowback, the filters will clog very easily!

A.2.4 Instrument Rack / Software

1 Switch on computer, monitor, Sir Galahad, Stream Selection box and Cavkit. Note: Before sampling Begins, the Galahad Analyzer be powered up for ~ 1 hour in order to let the mercury lamp warm up and stabilized.

2 Open the Mass Flow Controller Software.

3 Initialize the Mass Flow Controller by clicking on the green icon. Set the com port to "com 2". Set the mass flow controller to 25% then press "Set". This equates to a flow of 0.5 liter / min.

4 Open the PSA On/line software and enter the User name and Password

5 Select the appropriate sequence and the channels you want to analyze. (The PSA software manual has an excellent treatise on using the software properly.)

6 Press the start button (green triangle) on the Sequence page once all the preconditioning and filter boxes are at the correct temperatures and are operating normally.

A.2.5 Calibration Procedure

1. Carefully read through the PSA Galahad calibration section of the user manual (located in the PSA binder above the Pilot 3 computer in the CEMS trailer).

2. Remove the calibration vessel from its storage location and allow it to come to thermal equilibrium with its surroundings. (Usually 10 min).

3. On the 'instrument sequence' page of the PSA software select "once" for each the four calibration points.

4. If the software is currently on a different channel, it will finish the running of that channel before it proceeds to the next line of the sequence. When the cal sequence runs, fill out the temperature and volume spaces on the operator screen.

5. Condition the stainless steel syringe by drawing ~500 uL from the calibration vessel and immediately expelling the gas back into the vessel several times.

6. Carefully insert the syringe into the port of the calibration vessel and extract the appropriate volume of gas to be injected. The supplied syringes have a gas valve: green is open and red is closed. We typical use volumes of 200, 400 and 600 micro liters for the calibrations.

7. Inject the gas from the syringe into the calibration port of the Sir Galahad then press "OK" to start the calibration cycle. The software will activate the sequence of events. (After injection, look at the side port on the needle to ensure bits of the septum have not clogged the port).

8. Continue this procedure until the four calibration points are complete. Calibrations should occur at least once every other day. Typical calibration slopes are ~0.05. The correlation coefficient should be close to 0.999. Enter the calibration data into the Hg CEMs calibration log.

9. Some notes on calibration: If "0" is selected as one of the sequences, the entire previous calibration will be erased. To add a single point to a calibration, select a non-zero calibration sequence to run.

A.2.6 Cavkit and Zero Air Procedure

a. Turn the Cavkit unit on. Set the air pressure to ~25 psi. The temperature of the Cavkit unit should already be set at 40 deg C. The unit will blink with an AL showing until that temperature is reached.

b. Select the appropriate Cavkit / Blank sequence from the software. Care should be taken that Cavkits / Blanks are being run on only one unit at a time: The zero-air generator cannot produce enough flow to satisfy both simultaneously.

c. It usually takes two or three Cavkit runs (on the same channel) for the results to stabilize. Typically 5 –6 runs are done for a single channel before moving on to the next channel.

d. Once the Cavkit / Blank runs are finished, turn the air on the Cavkit unit back to 0 psi.

e. Blanks should be run every day on each instrument.

f. Cavkits are run usually every other day.

A.2.7 Correction Factor

The correction factor on the sequence page ("CF") is used in conjunction with the Mass Flow Controller value. The correction factor can be used to correct results for sample volume collected.

For example, if the Mass Flow Controller is set at 25%, this equates to a sampling flow rate of 0.5 l/min. The calibration units are normally picograms (pg). If the method used is a 1-minute method, then the results will be in pg/0.5 liters. In order to correct these units to pg/liter, a correction factor CF of 2 should be used. If a 2-minute method is used then with a CF of 1, then results will be in pg/liter. If a five-minute method is used with a correction factor CF of 1, then results will be given in pg/2.5 liters. To convert results to pg/l then the correction factor CF should be 1÷2.5, i.e.0.4.

As a rule, if the Mass Flow Controller is set at 25% (i.e. 0.5 l/min), then the correction factor CF is the inverse of 0.5 multiplied by the sampling time.

For a 1 minute method the Correction Factor CF is 1÷(0.5x1)=2.
For a 2 minute method the correction factor CF is 1÷(0.5x2)=1.
For a 5 minute method the Correction Factor CR is 1÷(0.5x5)=0.4.

If the Mass Flow Controller is set at a value other than 25% then the general equation for the Correction Factor CF is: 1÷[Method time x (Mass Flow Controller setting (%)÷50)].

A.3 Typical Alarms

1. Gas Alarms. There are two types of gas alarms to contend with. Argon and cooling gas (zero air). The instrument cannot run without a supply of argon and cooling air.

    a. If the argon pressure drops below **25 psi**, an alarm will activate and shut the instrument down. (The pumps and precondition units however will continue to run normally.)

    b. The same is true for zero-air supplied to the instruments.

    c. If either of these occurs, fix the problem (new cylinder etc.)

    d. Go to the alarms page on the software. “Acknowledge” the alarm then hit the “force reset” button.

    e. You should be able to resume sampling by pushing the green arrow on the sequence page.

2. Water Slip Alarms.

    a. There are three water slip detectors in each conditioning box. Two are attached (in series) with the Hg^T and the Hg^0 sample lines. The third is on the tray underneath the impingers.

    b. Stop the software by hitting the “pause” button on the instrument sequence page.

    c. If the water slip alarms trigger, the pumps (sample and peristaltic) will shut down. An alarm signal will be sent to the computer. The water slip indicator lights for both the Hg^0 and Hg^T sample lines are the leftmost set (underneath the channel #1 label).

    d. Turn the orange pump power switch off and disconnect the impingers from the flue gas sample lines. If this is not done, the sample pump and peristaltic pump will start once the slip detector is dry.

    e. If the impinger water slip lights are on – remove the slip detector from its’ socket, clean and dry the detector head, clean and dry the detector socket.

f. If any liquid collects in the tray underneath the impingers a contact will close, shut down the pumps and send an alarm signal back to the instrument computer. Clean up the liquid, dry and clean the contacts.

g. Reconnect the impingers, restart the sample pumps and restart the analyzer software by hitting the green arrow on the instrument sequence page.

3. Clogged Waste Impingers.

   a. If the waste impingers become clogged with Tin oxide (a black, gooey precipitate) they must be unclogged and cleaned before fluid builds up in the waste impinger and spills into the water slip detector.

   b. Stop the software by hitting the "pause" button on the instrument sequence page.

   c. Stop the pumps (orange switch in back of conditioner).

   d. Disconnect the top of the NaOH waste impinger

   e. Disconnect the bottom of the waste impinger and drain the fluid into a small graduated cylinder.

   f. Clean the waste lines from the bottom of the impinger, through the peristaltic pump and into the waste container with DI water. The pump cassette head should be raised to allow fluid to drain / be pushed through. Reattach waste lines and click down the pump head.

   g. Put about 20 – 40 mL NaOH solution (from one of the VWR boxes) into the waste impinger. This will dissolve any remaining precipitate in about 5 minutes.

   h. Reattach waste lines and impinger tops.

   i. Start the pump (orange power switch)

   j. Start sampling again at the software.

k. *The black precipitate occurs only in the NaOH impingers and is indicative of too much flue gas flowing though the impingers. The flow rate should be turned down to below 2 liters per minute. This is done using the blue Teflon valve on top of the conditioner hot box.*

For any other types of problems involving sampling, conditioners, sample probes, operations, the Galahad analyzer etc., refer to the troubleshooting guide for more extensive ideas.

A.4 Hourly Checks

Mercury Instrument Check Sheet: Guide for Burger Pilot Operators

This document is intended to be a guide for the operators while making frequent observations of the mercury CEMs. In the recent past, one of the components of the mercury CEMs failed and catastrophic damage to the analyzer ensued. These instruments are very delicate and are prone to failure at any time. They are also not very good about protecting themselves. It is imperative, however, that the Hg CEMs run continuously. To this end, it is necessary that the operators frequently check operation of the instruments to prevent failures and damage. There are several simple checks to make and a list of actions to take in case problems do arise.

We currently measure mercury from two different locations at the pilot: an inlet sample and an outlet sample. The inlet sample is located on the east side below the single tube reactor platform. The outlet measurement is made from the return duct on the west side of the pilot. There are five items that must be checked on an hourly basis: (1) the inlet sample probe (QSIS filter), (2) the inlet conditioner, (3) the outlet sample probe, (4) the outlet conditioner and (5) the instrument rack located in the CEMs trailer.

A.4.1. Inlet (QSIS) Sample Pump / Filter

The QSIS filter / pump is designed to extract and ash free sample of flue gas and send it to the inlet conditioner. Gas flowing through the filter and sample pump must be kept warm in order to avoid condensation. To do this there are two heaters with temperature controllers on the QSIS probe and a heated sample box for the pump. The first probe controller (labeled Plumbing Temp) keeps the flange and probe attachment plumbing warm. This temperature should be between 280 and 300 ^oF (as shown in the table below). The second heater is the probe's high temperature jacket heater (labeled Jacket Temp) and it should be kept between 380 and 420 ^oF. The sample probe interior temperature is ~400 ^oF, however, there is no readout for the temperature. The only indication the operators will have is that the exterior of the sample probe hotbox is warm to the touch.

Flow thought the QSIS filter assembly is measured using a venturi flowmeter. A magnehelic gage (labeled Venturi DP) reading differential pressure across the venturi meter indicates flow. The DP reading should be greater than 15" wc. A reading of less than 15” indicates reduced flow through the probe, which will result in improper probe operation and sample contamination. The filtered gas sample is drawn from the QSIS probe by the heated sample pump. The pump must be running, and the box that the pump head in has to hot.

Item to Check	Correct Condition	Action to Take
Plumbing Temp	280 - 300 deg F	Call Hg CEMs Engineer
Jacket Temp	380 - 420 deg F	Call Hg CEMs Engineer
Venturi DP	> 15"	Call Hg CEMs Engineer
Pump Operating	running	Secure the instruments - call Hg CEMs Engineer
Sample Pump Temp	warm	Call Hg CEMs Engineer

A.4.2. Outlet Sample Pump

The outlet sample pump is easy to check. Just make sure the pump is running and that the box containing the heaters and pump head is warm to the touch.

A.4.3. Inlet Conditioners

The conditioners operate as small, automated chemistry labs that prepare the gas samples before sending them to the analyzer. When checking the inlet conditioner, the first thing to look at is the control board. There should be four green lights showing above the “water slip” labels. If any liquid get into the sample lines, the two water slip detector lights will go out and shut the conditioner down – meaning the sample pump will stop and the reagent pump will also stop. This is bad and if it happens, secure the instruments and Hg CEMs Engineer should be notified immediately.

The next items to examine are the waste impingers. These are the two glass tubes on the right side of the conditioner. These tubes collect condensed moisture and spent reagents. The peristaltic pump in the conditioner takes the waste out of these impingers and dumps it into the waste tank. It is very important that these waste impingers do not clog up. If they do, liquid will spill into the sample line and set off the water slip detectors. If fluid is build up over the red line on the waste impingers, secure the instruments and notify Hg CEMs Engineer immediately.

On the left side of the conditioner there are two glass tubes filled with liquid (reagents) that have flue gas bubbling through them. In examining these impingers, there are several things to look at. The first and most obvious are “bubbles”. Does the bubbling look like it’s occurring at the usual rate (2 liters per minute)? If not, Hg CEMs Engineer should be called and directions will be given over the phone. In addition to bubbling, the fluids in the impingers should be clear. Problems have arisen with the instruments when the fluids are discolored – instead of being clear, these fluids turn milky white then eventually black. If this happens, the conditioners are bound to fail. Call Hg CEMs Engineer.

There are several other minor items to check on the inlet conditioner. The temperature controllers labeled "hot box controller" and "heated line controller" should be reading between 395 and 405 deg F. There should be no T/C alarms (thermocouple). These alarms will illuminate the T/C failure light on the control board.

The reagent containers underneath the conditioners should also be checked. Both the KCl container and NaOH containers should have liquid levels above the red lines marked near the bottom. With the waste container, it should not be allowed to get above the red line and spill over into the bins. If it looks like this is going to happen, pull the two Teflon waste lines out of the waste container, dump the container contents into the waste tank, and then replace the lines. **Caution must be taken when emptying the waste container: the liquid is extremely caustic. Safety glasses and vinyl gloves must be used. Make sure that you do not inadvertently dump the KCl or NaOH containers.**

Item to Check	Correct Condition	Action to Take
Control board	4 green lights	Secure the instruments, Call Hg CEMs Engineer
right impingers	draining	Secure the instruments, Call Hg CEMs Engineer
left impingers	bubbling	Secure the instruments, Call Hg CEMs Engineer
left impingers	clear fluid	Secure the instruments, Call Hg CEMs Engineer
cooler temp	4 - 6 deg C	Secure the instruments, Call Hg CEMs Engineer
hot box controller	395 - 405 deg F	Call Hg CEMs Engineer
heated line controller	395 - 405 deg F	Call Hg CEMs Engineer
thermocouple alarms	none	Call Hg CEMs Engineer
reagent containers	Above the red line	Call Hg CEMs Engineer
waste container	Below the red line	Empty the container

A.4.3 Instrument Rack

The mercury analyzers can be found inside the CEMs trailer and several things needed to be checked there as well. On the side of the instrument rack there is a small flow meter. This flow meter measures "excess" flow through the analyzer. There should always be excess flow – if not, our sample is being diluted and the instrument reports incorrect data. If there is not excess flow, wait 10 seconds and look again. Then if there still is not excess flow, call Hg CEMs Engineer

There is a mass flow controller (MFC) in the instruments that regulates the flow through the analyzer. The readout for the MFC can be found on the computer screen. If the MFC is not reading between 24.5 and 25.5, something has gone wrong and the instruments must be secured. There is also a readout on the computer screen labeled

“Current Alarm Severity”. If this does not read as “None” something has gone wrong. If this is the case, call Hg CEMs Engineer.

Item to Check	Correct Condition	Action to Take
correct excess flow	between 1 and 2	Call Hg CEMS Engineer
mass flow controller	24.5 – 25.5	Secure the instruments – call Hg CEMS Engineer
instrument alarms	none	Call Hg CEMS Engineer

A.5 Hg CEMs Shutdown Procedure

1. Press the “Stop” button (red square) on the instrument sequence page. The unit will finish the current sequence and then perform the instrument shutdown sequence (at most this will take 10 minutes).

2. Open the back of the preconditioning units and turn off the pumps.

3. Disconnect the Hg^0 and Hg^T sample lines from the top of the water slip indicators then disconnect the Hg^0 and Hg^T impingers. (This keeps reagents from being drawn into the heated sample line). The Hg^0 lines should be disconnected last.

4. *If the instruments are to be shut down for longer than 5 days*, switch all the orange switches in the back of the Preconditioning unit to the “off” position (pumps, coolers, heated line and hotbox).

5. Release the tension on the peristaltic pump cassettes.

6. *If the instruments are to be shut down for longer than 5 days*: unplug the Preconditioning units and the sample filter hotboxes.

7. Exit the PSA Online software and Mass Flow Controller software.

8. The Cavkit unit and stream selector units should be turned off. The Sir Galahad does not like to be turned off: Leave it on always.

9. Turn off the zero-air generator; close the valve for the blowback air; and close the argon cylinder.

10. Turn of the air for the mercury addition system. Turn of the water bath for the Hg addition system. Turn of the boiler heating tape controller for the Hg addition system.

A.6 Daily Maintenance

1. Each Sir Galahad instrument should be calibrated daily. A calibration log is kept in the front of the procedures manual.

2. A detector test should be conducted on each analyzer daily.

3. Blow back sample lines

    a. Secure the Hg CEMs
    b. Disconnect all the sample lines from the impingers and the water slip indicators. Wrap the end of the sample lines with a wipe-all to avoid spraying the inside of the conditioner with water (if any).
    c. Run compressed air through each line for at least two minutes. The two sample lines must be dried. The cost of not performing this duty is $1200 for a new mass flow controller (or damage to the Sir Galahad instrument).
    d. Restart the Hg CEMs

4. Gas cylinders: Ensure that the argon cylinder is not empty.

5. Empty the waste reagent container daily. It is difficult to clean up waste reagent that has overflowed the waste container.

6. Check the water level in the mercury addition system bath. The water should be as high as possible without spilling into the boiler container.

A.7 Weekly Maintenance

1. Change peristaltic pump tubes
    a. The waste tubes are colored *purple-white.*
    b. The KCl reagent tubes are colored *yellow-blue*.
    c. The NaOH reagent tubes are colored *purple-purple* (The exception is in conditioner 3 the tube is colored *purple-purple* and is drained by two waste lines (*purple-white* tubes "T" together).

2. Dump the data to a floppy disk
    a. Go to the "reporting" page on the PSA software
    b. Select the dates, times and instruments you want
    c. Select all the information to be reported
    d. Save the generated report to an Excel file under (a name to be determined)

e. The computers will soon be hooked up to the network, thereby eliminating this chore.

3. Clean the sample probes and install new ceramic filters. The heated sample lines leading from the probes to the conditioners should be rinsed with DI water as well.

4. Clean the conditioners. This includes (i) the tubing and valves in the conditioner hotbox, (ii) the reagent impingers, (iii) the condensing impingers, (iv) the water slip detectors, (v) the sample lines from the water slip detectors. Clean the overflow tray in the bottom of the conditioner.

5. The reagent containers should be emptied, cleaned and rinsed with DI water.

A.8 Monthly Maintenance

1. Rinse the heated sample lines with 10% nitric acid solution then rinse with DI water.
2. Check the mercury levels in the Hg addition system boiler
3. Rinse the sample lines running from the CEMs trailer to the conditioners with DI water.

A.9 Troubleshooting Guide

Baldwin Probe

Observed Fault	Possible Causes	Action to Take
Clogged filters	i. Blowback not being performed ii. Blowback air unavailable or pressure low iii. Filter is old	i. Select correct cycle in software ii. Set blowback air to 90 psi iii. Replace as needed
Probe temperature low	i. Probe heaters unplugged ii. Heaters disconnected iii. Circulation fan inoperative iv. Bad probe controller circuit board v. Bad thermocouple connection vi. Thermostat set too low	i. Plug in sample probe ii. Check heater wiring, repair as needed iii. Troubleshoot fan iv. Troubleshoot circuit board v. Check thermocouple for connection and correct operation vi. Reset thermostat
Sample pump stopped	i. Conditioner Alarm (water slip, blowback etc.) ii. Pump control cable loose iii. Sample pump circuit breaker in conditioner tripped iv.	i. Clear alarm condition ii. Check pump control cable at probe end and conditioner end iii. Reset circuit breaker, replace as needed iv.
Low sample gas flow (< 6 lpm)	i. Filter clogged ii. Teflon lines disconnected or ruptured iii. Sample lines clogged iv. Pump diaphragm / head punctured /loose v. Probe stinger clogged	i. Replace as needed ii. Check Teflon lines for integrity. Repair as needed iii. Clear as needed iv. Install pump repair kit. Tighten pump head. Leak check. v. Clear stinger

QSIS Probe

Observed Fault	Possible Causes	Action to Take
No flow or low flow on venturi pressure gauge	i. Isolation valves are closed or only partially open ii. Pressure gauge not zeroed iii. Gast blower power off iv. Gas blower impeller jammed v. Leak in air line system vi. Pressure taps on venturi are plugged	i. Fully open both isolation valves ii. Zero pressure gauge iii. Turn on blower iv. Clear impeller jam, restart by hand if necessary v. Ensure all fittings are secure and supply lines are free of damage vi. Check ports and lines. Clean and replace as needed. Clean venturi taps using compressed air
Temperature of probe below operational limits	i. Electrical power disconnected ii. Duct temperature low iii. Loose T/C leads iv. Heater burned out	i. Check electrical connections ii. Verify with plant operators iii. Check and replace as needed iv. Replace heater. QSIS filter may need replacement if corroded.
Ash contamination downstream of QSIS filter	i. QSIS filter is cracked	i. Pressure test QSIS filter element. Replace as needed
Poor CAVkit results	i. QSIS filter is dirty / contaminated	i. Clean filter. Check CAVkit results downstream of filter.

Galahad Analyzer

Observed Fault	Possible Causes	Action to Take
Power LED not illuminated	i. Power not switched at instrument rack ii. Power not on at rear of instrument iii. Fuses in mains socket blown. iv. Internal problem	i. Switch on instrument rack power ii. Switch on instrument power iii. Replace fuses with caution (only once) iv. Call Hg CEMs engineer
Serial LED illuminated	i. RS232 communications problem	i. Check all cable connections / cycle analyzer power. Reboot computer if needed.
Gas 1 LED flashing	i. Carrier gas not present or low pressure	i. Connect gas or increase pressure to 35 psi minimum
Gas 2 LED flashing	i. Cooling gas not present or low pressure	i. Connect gas or increase pressure to 35 psi minimum
Display over-range at all times	i. Contamination of measurement chamber ii. System contamination	i. Flush the system with argon ii. Inspect the measurement chamber for contamination iii. Call Hg CEMs engineer
Display always reading between 750-1250 and does not change when sample is introduced	i. Wrong mode selected in software	i. Select ratio mode
Loss of sensitivity	i. Blocked injection needle ii. Faulty lamp iii. Lens fogged iv. Faulty PMT v. Faulty valve switching	i. Change / clear needle ii. Replace the lamp iii. Clean the lens iv. Call Hg CEMs engineer v. Replace valve / drawer
Noisy baseline	i. Faulty power supply ii. Faulty PMT iii. Faulty lamp iv. Contamination	i. Call Hg CEMs engineer ii. Call Hg CEMs engineer iii. Replace the lamp iv. Call Hg CEMs engineer
Poor Reference and Emission readings on detector test	i. Lens fogged	i. Clean the lens
Gain not changing correctly	i. Faulty power supply ii. Internal loose cable	i. Call Hg CEMs engineer ii. Check cabling
No sample signal seem	i. Heater coil open circuit ii. Blocked injection needle	i. Call Hg CEMs engineer ii. Replace needle
Will not proceed through cycle	i. Incorrect mode selected ii. Electronic problem	i. Select correct mode ii. Call Hg CEMs engineer

Observed Fault	Possible Causes	Action to Take
Double peaks on sample	i. Uneven winding on heater coil ii. Gold trap not positioned in heater assembly correctly iii. Overheating	i. Troubleshoot the heater coil ii. Troubleshoot the heater coil iii. Reduce heating time
Long “tail” on sample	i. No cooling or insufficient cooling ii. Insufficient carrier gas flow rate iii. Gold trap not positioned in heater assembly correctly iv. Insufficient vaporize time	i. Troubleshoot the cooling gas ii. Troubleshoot the carrier gas iii. Troubleshoot the heater assembly iv. increase the vaporize time
High blanks or baseline	i. Contamination of the drawer / valves	i. Replace the drawer / valves

Conditioning / Speciation Units

Observed Fault	Possible Causes	Action to Take
No gas flow or low gas flow through impingers	i. Conditioner power ii. Sample pump iii. Flow control valves set too low iv. Vent line valve set high v. Sample line clog vi. Sample line vent solenoids clogged vii. Slip alarm triggered viii. HSL disconnect	i. Power up conditioner, check circuit breakers ii. Check sample pump power / breaker iii. Adjust flow valves in conditioner hotbox iv. Adjust vent line valve v. Clean and clear all sample lines as needed vi. Clean and dry sample line vent solenoids vii. Clear slip by drying and cleaning slip detectors viii. Check sample line connections and integrity

Observed Fault	Possible Causes	Action to Take
Water slip alarm illuminated	i. Fluid in water slip detectors ii. Fluid in spill tray iii. Control board failure iv. Slip detector failure	i. Clean and dry slip detectors ii. Clean and dry spill tray contacts. iii. Check control board functionality by disconnecting slip detector leads. iv. Replace slip detectors as needed
No or little reagent delivery to impingers	i. Tension ratchets on peristaltic pump tube assembly loose ii. Peristaltic pump tube capillary clogged iii. Peristaltic pump motor failure iv. Peristaltic pump tubes are worn / damaged	i. Correctly tension ratchets ii. Check capillaries and clean as needed iii. Check sample pump circuit breaker. Troubleshoot motor. Replace as needed iv. Replace tubes as needed
Hotbox temperature incorrect	i. Wrong set temperature ii. Controller failure iii. Wrong thermocouple type programmed iv. T/C failure	i. Set correct temperature ii. Troubleshoot controller. Replace as needed iii. Reprogram controller for "K" type T/C iv. Check T/C connection on control board. Replace as needed.
Heated sample line temperature incorrect	i. Wrong set temperature ii. Controller failure iii. Wrong thermocouple type programmed iv. T/C failure	i. Set correct temperature ii. Troubleshoot controller. Replace as needed iii. Reprogram controller for "K" type T/C iv. Check T/C connection on control board. Replace as needed.

Observed Fault	Possible Causes	Action to Take
T/C failure light illuminated	i. T/C failed ii. T/C disconnected from control board iii. Control board failure	i. Replace as needed ii. Check T/C connect iii. Troubleshoot board and replace as needed
Pelletier cooler failure	i. T/C placement incorrect ii. Ceramic elements damaged iii. Power supply failure iv. Control board failure v. Cooler power leads disconnected	i. Check T/C placement ii. Inspect ceramic cooling elements for damage. Replace as needed iii. Troubleshoot cooler power supply iv. Troubleshoot cooler control board v. Check cooler power leads for proper connection
Permanent alarm/blowback mode	i. Alarm cable disconnected ii. Faulty signal from instrument rack	i. Check conditioner alarm cable at instrument rack and conditioner ii. Cycle power at instrument rack
Clogged reagent / waste impingers	i. Gas flow > 2 lpm ii. Peristaltic pump tube attached to drain expired iii. Reagents expired iv. Reagents introduced to impinger at incorrect location v. Ambient conditioner temperature too high	i. Decrease gas flow below 2 lpm ii. Install new peristaltic pump tubes iii. Mix new reagents iv. Reagents should be sent to impinger through gas exit ports v. Cool conditioner with fan
Waste impinger frozen	i. Pelletier cooler temperature set too low ii. T/C placement in heat exchanger block	i. Reset cooler set point to 5 deg C ii. Ensure proper placement
Discolored reagents in impingers	i. Reagent refresh rate too low ii. Peristaltic pump tube tension too low iii. Reagents expired	i. Increase reagent refresh rate with larger / new peristaltic pump tubes ii. Check peristaltic pump tube tensioning ratchet iii. Mix new reagents

Hg CEMs Operations

Observed Fault	Possible Causes	Action to Take
Bad calibration	i. Side port needle clogged ii. Incorrect volumes / temperatures used iii. Needle not conditioned iv. Septa on analyzer calibration port expired v. Septa on calibration vessel expired vi. Analyzer PMT damaged vii. Analyzer Hg lamp damaged	i. Clear clog. Replace needle as needed. ii. Redo calibration sequence with correct volume and temperature input iii. Condition needle iv. Replace septa as needed v. Replace septa as needed vi. Perform detector test to identify and confirm. Notify Hg CEMs engineer. vii. Perform detector test to identify and confirm. Notify Hg CEMs engineer.
Poor Blank results	i. Ash contamination ii. Reagents contaminated iii. CAVkit pressure too high	i. Check for contamination. Clean sampling system as needed ii. Clean reagent reservoirs and capillaries. Mix new reagents iii. Reduce the CAVkit pressure to 25 psi
Poor CAVkit results	i. Ash contamination on filter ii. Ash contamination in sample line iii. Sampling system fouled iv. Stream selector valve not operating correctly v. Inadequate sample flow to instrument rack	i. Replace filter, clean probe ii. Rinse and dry sample line iii. Clean sampling system iv. Troubleshoot stream selector. Replace valve as needed. v. Adjust sample flow at conditioner: analyzer needs a minimum of 0.5 lpm sample

Observed Fault	Possible Causes	Action to Take
Mass flow controller not operating properly	i. Exhaust line clogged ii. Sample pump stopped or disconnected from stream selector. iii. Moisture in MFC iv. MFC not set to “COM2”	i. Check exhaust line for ice and unclog. ii. Check fuse as well pump power. Check stream selector connections and selector power source iii. Clean, dry MFC and retest. Replace with spare if needed. iv. Set MFC to “COM2”. Close and restart MFC software.
No signals seen in Hg data	i. Check MFC setting for 25% setting ii. Conditioners / sample pumps not running iii. Stream selection power off iv. Sample lines disconnected v. Wrong sequence selected in PSA Online software vii. Sample capillary clogged / damaged viii. PMT / Hg lamp inoperative	i. Troubleshoot MFC as needed ii. Investigate conditioner for alarms / water slips. iii. Check stream selector power / fuse iv. Reconnect appropriate sample lines v. Select correct sequence vii. Replace capillary viii. Perform detector test to check PMT and lamp function
Hg0 level > HgT level for the same probe	i. Stream selector malfunction ii. Inadequate sample flow to instrument rack iii. HgT channel contaminated	i. Troubleshoot stream selector ii. Adjust sample flow at conditioner: analyzer needs a minimum of 0.5 lpm sample iii. Clean sampling system

A.10 Frequently Asked Questions

1. How do you recalibrate?

Go to the instrument sequence page and edit the sequence so that each of the calibration points is set to “Once”. When the sequence loops round it will prompt you to inject Hg vapor.

2. How do you add a single point to an existing calibration?

Edit the sequence so that only one of the calibration points is set to “Once”. Make sure that the selected point is not the zero point.

3. How do you edit an existing calibration?

Select the “Calibration” page and click on the “Edit” button. Then click on the “Instrument 1” button. In the calibration grid type “no” in the include column of the point you wish to ignore. Then press the “Recalibrate” button and the “Yes” button when asked if you want to continue.

4. How often should you change pump tubing?

After every three days of use the pump tubing can be moved over so that the second set of bridges are used for another three days. The pump tubing should be replaced every week if you are running continuously.

5. If you need more sensitivity because the mercury levels in your samples are low, what would you do?

You could change the sequence to use a longer method, i.e. change from a 1-minute method to a 5-minute method (remember to change the Correction Factor CF accordingly). Alternatively you could change the gain. Remember to change the gain on the calibration method also.

6. How would you look at a calibration used on a previous day?

Go to the “Reporting” page. Set the time from which you want to start looking at the data then set the time when you want to finish looking at the data. Select “Instrument 1” and the channels and data you want to look at then press the “Print Preview” icon on the right hand side of the screen. The calibration gradient, intercept and correlation coefficient will be given for each sample that was analyzed.

7. How would you export data to Excel or another software package?

Go to the “Reporting” page. Set the time from which you want to start looking at the data then set the time when you want to finish looking at the data. Select “Instrument 1” and the channels and data you want to look at then press the Export data” icon and save the data in the preferred location.

8. How could you test for any losses at the inlet or outlet Preconditioning units?

On the Sequence page select the channels for Hg^0 Inlet + Cavkit, Hg Total Inlet + Cavkit, Hg^0 Outlet + Cavkit and Hg Total Outlet + Cavkit. When these channels are analyzed, they should all give the same value.

9. How could you test for contamination at the inlet or outlet Preconditioning units?

On the Sequence page select the channels for Hg^0 Inlet + Blank, Hg Total Inlet + Blank, Hg^0 Outlet + Blank and Hg Total Outlet + blank. When these channels are analyzed they should all give the same low value.

10. How could you check that the sample flow rate delivered to the analyzer is sufficient?

The sample streams, which enter the analyzer, should be greater than 500 ml/min. There is a small flowmeter on the side of the instrument rack that measures sample excess flow. It should read ~1 scfh. The large blue Teflon valves in the conditioning boxes control this flow. They may have to be adjusted occasionally, especially after startup.

12. How could you check that the temperature in each of the Peltier coolers?

There is a temperature readout on the control board in each conditioner as well as a small silver toggle. Move the toggle to shift the display to the appropriate sampling channel. The temperature of the Peltier coolers should be between 4-6 °C.

13. What is the purpose of the KCl solution?

The purpose if the KCl solution is to provide a means to sequester oxidized mercury. Flue gas containing a mixture of oxidized and elemental mercury vapor will only have elemental mercury vapor after bubbling through the impinger filled with the KCl reagent.

14. What is the purpose of the $SnCl_2$/NaOH?

The purpose of the $SnCl_2$ is to act as a reducing agent. Any oxidized mercury will be reduced to elemental mercury in the presence of $SnCl_2$. The NaOH serves only to keep the $SnCl_2$ in solution. NaOH has the added benefit of scrubbing acid gases from the sampled flue gas.

15. What is the sampling flow rate at the Sir Galahad?

The Galahad analyzer requires a sample flow rate of 0.5 lpm. If it is not provided through the sample lines attached to the stream selector, the mass flow controller will pull from the stream selector exhaust, thereby diluting the sample.

16. If you had an alarm message "coms error", what would you do?

This alarm is an indication that the analyzer and the computer are not communicating correctly. Briefly cycling the power on analyzer has resolved this problem in the past. Rebooting the computer as well as the analyzer will also work.

17. How would you check that enough sample is being delivered to the analyzer?

The excess flow meter located on the side of the instrument rack will show the amount of excess flow for the particular channel being samples at that particular moment. (The channel being sampled will be indicated on the Instrument Sequence page of the PSA software). The excess flow rate for each channel should be observed frequently during the operation of the Hg CEMs.

Appendix B: Ontario Hydro Test Method

DRAFT

October 27, 1999

Standard Test Method for Elemental, Oxidized, Particle-Bound, and Total Mercury in Flue Gas Generated from Coal-Fired Stationary Sources (Ontario Hydro Method)[1]

1. Scope

1.1 This method applies to the determination of elemental, oxidized, particle-bound, and total mercury emissions from coal-fired stationary sources.

1.2 This method is applicable to elemental, oxidized, particle-bound, and total mercury concentrations ranging from approximately 0.5 to 100 µg/dscm.

1.3 This method describes equipment and procedures for obtaining samples from effluent ducts and stacks, equipment and procedures for laboratory analysis, and procedures for calculating results.

1.4 This method is applicable for sampling elemental, oxidized, and particle-bound mercury at the inlet and outlet of emission control devices and for calculating control device mercury collection efficiency.

1.5 Method applicability is limited to flue gas stream temperatures within the thermal stability range of the sampling probe and filter components.

1.6 The values stated in SI units are to be regarded as the standard. The values in parentheses are for information only.

1.7 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1.8 This standard assumes users are familiar with EPA stack-gas sampling procedures as stated in EPA Methods 1–4, Method 5, and Method 17.

2. Referenced Documents

2.1 *ASTM Standards:*
D 1193 Specification for Reagent Water[2]

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[1] This test method is under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres and is the direct responsibility of Subcommittee D22.03 on Ambient Atmospheres and Source Emissions.

[2] *Annual Book of ASTM Standards*, Vol. 11.01.

D1356 Definitions of Terms Relating to Atmospheric Sampling and Analysis[3]
D 2986 Evaluation of Air-Assay Media by the Monodisperse DOP (Dioctyl Phthalate) Smoke Test[3]
D 3154 Test Method for Average Velocity in a Duct (Pitot Tube Method)[3]
D 3685 Particulates Independently or for Particulates and Collected Residue Simultaneously in Stack Gases[3]
E 1 Specification for ASTM Thermometers[4]

2.2 *Other Standards:*[5]
EPA Method 1 – Sample and Velocity Traverses for Stationary Sources
EPA Method 2 – Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)
EPA Method 3 – Gas Analysis for the Determination of Dry Molecular Weight
EPA Method 4 – Determination of Moisture Content in Stack Gases
EPA Method 5 – Determination of Particulate Emissions from Stationary Sources
EPA Method 12 – Determination of Inorganic Lead Emissions from Stationary Sources
EPA Method 17– Determination of Particulate Emissions from Stationary Sources (In-Stack Filtration Method)
EPA Method 29 – Determination of Metals Emissions from Stationary Sources
EPA Method 101A – Determination of Particle-Bound and Gaseous Mercury Emissions from Sewage Sludge Incinerators
EPA Method 301 – Field Validation of Pollutant Measurement Methods from Various Waste Media
EPA SW 846 7470 – Mercury in Liquid Waste – Manual Cold Vapor Technique
EPA Water and Waste 600/4-79-020 – Methods for Chemical Analysis of Water and Wastes

3. Terminology

3.1 Definitions other than those given below in Sections 3.2, 3.3, and 3.4 are listed in ASTM D 1356.

3.2 *Definitions of Terms specific to the standard*:

3.2.1 *elemental mercury*—mercury in its zero oxidation state, Hg^0.

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[3] *Annual Book of ASTM Standards*, Vol. 11.03.

[4] *Annual Book of ASTM Standards, Vol 14.02.*

[5] Available from the U.S. Environmental Protection Agency’s Emission Measurement Technical Information Center or Code of Federal Regulations (40 CFR Part 60, Appendix A or 40 CFR Part 61, Appendix B).

3.2.2 *oxidized mercury*—mercury in its mercurous or mercuric oxidation states: Hg_2^{2+} and Hg^{2+}, respectively.

3.2.3 *elemental mercury catch*—mercury collected in the acidified hydrogen peroxide (HNO_3–H_2O_2) and potassium permanganate (H_2SO_4–$KMnO_4$) impinger solutions employed in this method. This is gaseous Hg^0.

3.2.4 *oxidized mercury* catch—mercury collected in the aqueous potassium chloride (KCl) impinger solution employed in this method. This is gaseous Hg^{2+}.

3.2.5 *particle-bound mercury catch*—mercury associated with the particulate matter collected in the front half of the sampling train.

3.2.6 *sample train*—complete setup including nozzle, probe, probe liner, filter, filter holder, impingers, and connectors.

3.2.7 *Impinger train*—setup includes only the impingers and connectors.

3.2.8 *front half of the sampling train*—all mercury collected on and upstream of the sample filter.

3.2.9 *total mercury*— all mercury (solid-bound, liquid, or gaseous) however generated or entrained in the flue gas stream (i.e., summation of elemental, oxidized, and particle-bound mercury).

3.3 *Symbols*:

A	=	cross-sectional area of stack, m^2 (ft^2)
B_{ws}	=	water vapor in the gas stream, proportion by volume
ΔH	=	average pressure differential across the orifice meter, kPa (in. H_2O)
Hg_{ash}	=	concentration of mercury in sample filter ash, µg/g
Hg^{tp}	=	concentration of particle-bound mercury, µg/dscm
Hg^0	=	concentration of elemental mercury, µg/dscm
Hg^{2+}	=	concentration of oxidized mercury, µg/dscm
IR	=	instrument reading from mercury analyzer, µg/L
L_p	=	leakage rate observed during the posttest leak check, m^3/min (cfm)
L_a	=	maximum acceptable leakage rate
M_s	=	molecular weight of stack gas, wet basis, g/g-mole (lb/lb-mole)
M_w	=	molecular weight of water, 18.0 g/g-mole (18.0 lb/lb-mole)
N	=	Normal conditions, defined as 0°C and 1 atmosphere pressure (in the U.S. N and standard conditions are the same in SI units)
P_{bar}	=	barometric pressure at the sampling site, kPa (in. Hg)
P_s	=	absolute stack gas pressure, kPa (in. Hg)
P_{std}	=	standard absolute pressure, 101.3 kPa (29.92 in. Hg)
R	=	ideal gas constant, 0.008314 kPa-m^3/K-g-mole (21.85 in. Hg-ft^3/°R-lb-mole)
T_m	=	absolute average dry gas meter temperature, K (°R)

T_s = absolute stack temperature, K (°R)
T_{std} = standard absolute temperature, 293 K (528°R)
V_D = total digested volume, mL
V_m = volume of gas sample as measured by dry gas meter, dcm (dscf)
$V_{m(std)}$ = volume of gas sample measured by the dry gas meter, corrected to standard conditions, dscm (dscf)
$V_{w(std)}$ = volume of water vapor in the gas sample, corrected to standard conditions, scm (scf)
W_{ash} = total mass of ash on sample filter, g
W_{lc} = total mass of liquid collected in impingers and silica gel, g (lb)
Y = dry gas meter calibration factor
θ = total sampling time, min
θ_1 = sampling time interval, from the beginning of a run until the first component change, min

4. Summary of Test Method

4.1 A sample is withdrawn from the flue gas stream isokinetically through a probe/filter system, maintained at 120°C or the flue gas temperature, whichever is greater, followed by a series of impingers in an ice bath. Particle-bound mercury is collected in the front half of the sampling train. Oxidized mercury is collected in impingers containing a chilled aqueous potassium chloride solution. Elemental mercury is collected in subsequent impingers (one impinger containing a chilled aqueous acidic solution of hydrogen peroxide and three impingers containing chilled aqueous acidic solutions of potassium permanganate). Samples are recovered, digested, and then analyzed for mercury using cold-vapor atomic absorption (CVAAS) or fluorescence spectroscopy (CVAFS).

5. Significance and Use

5.1 The measurement of particle-bound, oxidized, elemental, and total mercury in stationary-source flue gases provides data that can be used for dispersion modeling, deposition evaluation, human health and environmental impact assessments, emission reporting, compliance determinations, etc. Particle-bound, oxidized, and elemental mercury measurements before and after control devices may be necessary for optimizing and evaluating the mercury removal efficiency of emission control technologies.

6. Interferences

There are no known interferences, but certain biases may be encountered (See Section 16).

7. Apparatus

7.1 *Sampling Train*—similar to ASTM D 3685, EPA Method 5/EPA Method 17 and EPA Method 29 trains, as illustrated in Fig. 1.

7.1.1 *Probe Nozzle (Probe Tip)*—Glass nozzles are required unless alternate nozzles are constructed of materials that are free from contamination and will not interact with the sample. Probe fittings constructed of polytetrafluoroethylene (PTFE), polypropylene, etc., are required instead of metal fittings to prevent contamination.

7.1.2. *Probe Liner*—If the sample train is to be in EPA Method 5 configuration (out-of-stack filtration), the probe liner must be constructed of quartz or borosilicate glass. If an EPA Method 17 (in-stack filtration) sampling configuration is used, the probe/probe liner may be constructed of borosilicate glass, quartz or, depending on the flue gas temperature, PTFE.

7.1.3 *Pitot Tube*—Type S pitot tube. Refer to Section 2.2 of EPA Method 2 for a description.

7.1.4 *Differential Pressure Gauges*—inclined manometers or equivalent devices. Refer to Section 2.1 of EPA Method 2 for a description.

7.1.5 *Filter Holder* — constructed of borosilicate glass or PTFE-coated stainless steel with a PTFE filter support or other nonmetallic, noncontaminating support. Do not use a glass frit or stainless steel wire screen. A silicone rubber or PTFE gasket, designed to provide a positive seal against leakage from outside or around the filter, may be used.

7.1.6 *Connecting Umbilical Tube*—heated PTFE tubing. This tube must be heated to a minimum of 120°C to help prevent water and acid condensation. (The umbilical tube is defined as any tubing longer than 0.5 m that connects the filter holder to the impinger train).

7.1.7 *Probe and Filter Heating System*

7.1.7.1 *EPA Method 5 Configuration*—For EPA Method 5 configuration, the temperature of the flue gas, sample probe, and the exit of the sample filter must be monitored using temperature sensors capable of measuring temperature to within 3°C (5.4°F). The heating system must be capable of maintaining the sample gas temperature of the probe and exit of the sample filter to within ±15°C (±27°F) of the flue gas temperature. Regardless of the flue gas temperature, to prevent water and acid condensation, at no time must the probe temperature, sample filter exit gas temperature, or the temperature of the connecting umbilical cord be less than 120°C.

7.1.7.2 *EPA Method 17 Configuration*—For EPA Method 17 configuration, the sample filter is located in the duct and, therefore, naturally maintained at the flue gas temperature. The heating system is only required to maintain the probe and connecting umbilical cord to at least 120°C. If the flue gas temperature is less than 120°C, then EPA Method 5 configuration must be used.

7.1.8 *Condensing/Absorbing System*—consists of eight impingers immersed in an ice bath and connected in series with leak-free ground glass fittings or other noncontaminating leak-free fittings. (At no time is silicon grease or other greases to be used for this method). The first, second, fourth, fifth, sixth, and eighth impingers are of the Greenburg–Smith design modified by replacing the standard tip with a 1.3-cm (0.5-in.)-ID straight glass tube extending to about 1.3 cm (0.5 in.) from the bottom of the flask. The third and seventh impingers are also Greenburg–Smith design, but with the standard tip including the glass impinging plate. The first, second, and third impingers contain aqueous 1 N potassium chloride (KCl) solution. The fourth impinger contains an aqueous solution of 5%$^V/_V$ nitric acid (HNO_3) and 10% $^V/_V$ hydrogen peroxide (H_2O_2). The fifth, sixth, and seventh impingers contain an aqueous solution of 4%$^W/_V$ potassium permanganate ($KMnO_4$) and 10%$^V/_V$ sulfuric acid (H_2SO_4). The last impinger contains silica gel or an equivalent desiccant. Refer to Note 1.

Note 1—When flue gas streams are sampled with high moisture content (>20%), additional steps must be taken to eliminate carryover of impinger contents from one sample type to the next. These steps must include use of oversized impinger(s) or use of an empty impinger between the KCl and HNO_3–H_2O_2. If a dry impinger is used, it must be rinsed as discussed in Section 13.2 of this method and the rinse added to the preceding impinger.

7.1.9 *Metering System*—vacuum gauge, leak-free pump, thermometers capable of measuring temperature to within 3°C (5.4°F), and a dry gas meter or controlled orifice capable of measuring volume to within 2%.

7.1.10 *Barometer*— barometer capable of measuring atmospheric pressure to within 0.33 kPa (0.1 in. Hg). In many cases, the barometric reading may be obtained from a nearby National Weather Service station, in which case, the station value (which is the absolute barometric pressure) shall be requested. An adjustment for elevation differences between the weather station and sampling point shall be applied at a rate of negative 0.33 kPa (0.1 in. Hg) per 30 m (100 ft) elevation increase or vice versa for elevation decrease.

7.1.11 *Gas Density Determination Equipment*—temperature sensor and pressure gauge, as described in Section 2.3 and 2.4 of EPA Method 2. The temperature sensor shall, preferably, be permanently attached to the pitot tube or sampling probe in a fixed configuration, such that the sensor tip extends beyond the leading edge of the probe sheath and does not touch any metal. Alternative temperature sensor configurations are described in Section 2.1.10 of EPA Method 5. If necessary, a gas analyzer can be used to determine dry moleculer weight of the gas (refer to EPA Method 3).

7.2 *Digestion Apparatus*

7.2.1 *Dry Block Heater or Hot Water Bath*—a heater capable of maintaining a temperature of 95°C is required for digestion of samples, similar to that described in EPA SW846 Method 7470.

7.2.2 *Ice Bath*

7.2.3 *Digestion Flasks*—Use 50- to 70-mL tubes or flasks with screw caps that will fit a dry block heater. For a water bath, 300-mL biological oxygen demand bottles for SW846 Method

7470 are to be used. In addition, borosilicate glass test tubes, 35- to 50-mL volume, with rack are needed.

7.2.4 *Microwave or Convection Oven and PTFE Digestion Vessels*—120 mL, or equivalent digestion vessels with caps equipped with pressure relief valves for the dissolution of ash, along with a capping station or the equivalent to seal the digestion vessel caps. Use a vented microwave or convection oven for heating. In addition, polymethylpentene (PMP) or equivalent volumetric flasks are recommended for the digested ash solutions.

7.3 *Analytical Equipment*—dedicated mercury analyzer or equivalent apparatus for the analysis of mercury via CVAAS. Alternatively, CVAFS may be used. CVAAS is a method based on the absorption of radiation at 253.7 nm by mercury vapor. The mercury is reduced to the elemental state and aerated from solution in a closed system. The mercury vapor passes through a cell positioned in the light path of an atomic absorption spectrometer. Absorbency is measured as a function of mercury concentration. A soda-lime trap and a magnesium perchlorate trap must be used to precondition the gas before it enters the absorption cell.

8. Reagents and Materials

8.1 *Purity of Reagents*—Reagent-grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.[6] Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

8.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean reagent water as defined by Type II in ASTM Specification D 1193.

8.3 *Reagents:*

8.3.1 *Boric Acid (H_3BO_3)*—purified reagent grade.

8.3.2 *Hydrochloric Acid (HCl)*—trace metal-grade concentrated hydrochloric acid, with a specific gravity of 1.18.

8.3.3 *Hydrofluoric Acid (HF)*—concentrated hydrofluoric acid, 48%–50%.

8.3.4 *Hydrogen Peroxide (H_2O_2)*—30% $^{V}/_{V}$ hydrogen peroxide.

8.3.5 *Hydroxylamine Sulfate ($NH_2OH \cdot H_2SO_4$)*—solid.

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[6] "Reagent Chemicals, American Chemical Society Specifications," Am. Chemical Soc., Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see "Reagent Chemicals and Standards," by Joseph Rosin, D. Van Nostrand Co., Inc., New York, NY, and the "United States Pharmacopeia."

8.3.6 *Hydroxylamine Hydrochloride ($NH_2OH \cdot HCl$)*—10% solution

8.3.6 *Sodium Chloride (NaCl)*—solid.

8.3.7 *Mercury Standard Solution*—a certified (1000 µg/mL) mercury standard.

8.3.7 *Nitric Acid (HNO_3)*—trace metal-grade concentrated nitric acid with a specific gravity of 1.42.

8.3.8 *Potassium Chloride (KCl)*—solid.

8.3.9 *Potassium Permanganate ($KMnO_4$)*—solid.

8.3.10 *Potassium Persulfate ($K_2S_2O_8$)*—solid.

8.3.11 *Stannous Chloride ($SnCl_2 \cdot 2H_2O$)*—solid.

8.3.12 *Sulfuric Acid (H_2SO_4)*—trace metal-grade concentrated sulfuric acid, with a specific gravity of 1.84.

8.4 *Materials:*

8.4.1 *Indicating Silica Gel*—with a size of 6–16 mesh.

8.4.2 *Crushed or Cubed Ice.*

8.4.3 *Sample Filters*—quartz fiber filters, without organic binders, exhibiting at least 99.95% efficiency (<0.05% penetration) for 0.3-µm dioctyl phthalate smoke particles and containing less than 0.2 µg/m^2 of mercury. Test data provided by filter manufacturers and suppliers stating filter efficiency and mercury content are acceptable. However, if no such results are available, determine filter efficiency using ASTM Test Method D 2986, and analyze filter blanks for mercury prior to emission testing. Filter material must be unreactive to sulfur dioxide (SO_2) or sulfur trioxide (SO_3).[7]

8.4.4 *Filter Papers*—for filtration of digested samples. The filter paper must have a particle retention of >20 µm and filtration speed of >12 sec.

8.4.5 *Nitrogen Gas (N_2)*—carrier gas of at least 99.998% purity. Alternatively, argon gas may be used.

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[7] Felix, L.G.; Clinard, G.I.; Lacey, G.E.; McCain, J.D. "Inertial Cascade Impactor Substrate Media for Flue Gas Sampling," U.S. Environmental Protection Agency, Research Triangle Park, NC 27711, Publication No. EPA-600/7-77-060; June 1977, 83 p.

8.4.6 *Soda Lime*—indicating 4- to 8-mesh absorbent for trapping carbon dioxide.

8.4.7 *Sample Containers*—glass with PTFE-lined lids.

8.5 *Sampling Reagents*

8.5.1 *KCl Absorbing Solution* (1 mol/L)—Dissolve 74.56 g of KCl in 500 mL of reagent water in a 1000-mL volumetric flask, swirl to mix, and dilute to volume with water. Mix well. A new batch of solution must made prior to each field test.

8.5.2 *HNO_3–H_2O_2 Absorbing Solution* (5% $^V/_V$ HNO_3, 10% $^V/_V$ H_2O_2)—Add slowly, with stirring, 50 mL of concentrated HNO_3 to a 1000-mL volumetric flask containing approximately 500 mL of water, and then add carefully, with stirring, 333 mL of 30% $^V/_V$ H_2O_2. Dilute to volume with water. Mix well. A new batch of solution must made prior to each field test.

8.5.3 H_2SO_4-*$KMnO_4$ Absorbing Solution* (4% $^W/_V$ $KMnO_4$, 10% $^V/_V$ H_2SO_4)—Mix carefully, with stirring, 100 mL of concentrated H_2SO_4 into approximately 800 mL of water. When mixing, be sure to follow standard acid to water addition procedures and safety precautions associated with strong acids. Then add water, with stirring, to make 1 L. This solution is 10% $^V/_V$ H_2SO_4. Dissolve, with stirring, 40 g of $KMnO_4$ into 10% $^V/_V$ H_2SO_4, and add 10% $^V/_V$ H_2SO_4, with stirring, to make 1 L. (**Warning**—See 9.1.1). H_2SO_4–$KMnO_4$ absorbing Solution must be made daily.

8.6 *Rinse Solutions for Sample Train*

8.6.1 *0.1 N HNO_3 Solution*—A certified reagent grade 0.1 N HNO_3 solution can be purchased directly or can be made by slowly adding 12.5 mL of concentrated HNO_3 to a 2000-mL volumetric flask containing approximately 500 mL of water, then diluting with water to volume.

8.6.2 *10%% $^W/_V$ HNO_3 Solution*—Mix carefully, with stirring, 100 mL of concentrated HNO_3 into approximately 800 mL of water. When mixing, be sure to follow standard acid to water addition procedures and safety precautions associated with strong acids. Then add water, with stirring, to make 1 L.

8.6.3 *10% $^W/_V$ Hydroxylamine solution*—Add 100 g Hydroxylamine sulfate and 100 grams sodium chloride to a 1000-mL volumetric flask containing approximately 500 mL of water. After the Hydroxylamine sulfate and sodium chloride has been dissolved, dilute with water to volume. As an alternative a 10% hydroxylamine hydrochloride solution can be used in all cases as a replacement for the hydroxylamine sulfate/sodium chloride solution.

8.7 *Sample Digestion Reagents*:

8.7.1 *Boric Acid Solution (4% $^W/_V$)*—Dissolve 4 g H_3BO_3 in water, and dilute to 100 mL.

8.7.2 *Aqua Regia ($HCl:HNO_3$ 3:1)*—Add 3 parts concentrated HCl to 1 part concentrated HNO_3. Note that this should be made up in advance and allowed to form a dark orange color. This mixture should be loosely capped, as pressure will build as gases form.

8.7.3 *Saturated Potassium Permanganate Solution (5%$^{W}/_{V}$)*—Mix 5 g $KMnO_4$ into water, dilute to 100 mL, and stir vigorously.

8.7.4 *Potassium Persulfate Solution (5%$^{W}/_{V}$)*—Dissolve 5 g $K_2S_2O_8$ in water, and dilute to 100 mL.

8.8 *Analytical Reagents*:

8.8.1 *Hydrochloric Acid Solution (10%$^{V}/_{V}$)*—Add 100 mL concentrated HCl to water, and dilute to 1 L. Be sure to follow all safety precautions for using strong acids.

8.8.2 *Stannous Chloride Solution (10%$^{W}/_{V}$)*–Dissolve 100 g in 10%$^{V}/_{V}$ HCl, and dilute with 10%$^{V}/_{V}$ HCl to 1 L. Difficulty in dissolving the stannous chloride can be overcome by dissolving in a more concentrated HCl solution (such as 100 mL of 50%$^{V}/_{V}$ HCl) and diluting to 1 L with water. Note that care must be taken when adding water to a strong acid solution. Add a lump of mossy tin (~0.5 g) to this solution.

8.9 *Mercury Standards*:

8.9.1 *10 mg/L Hg Stock Solution*—Dilute 1 mL of 1000 mg/L Hg standard solution to 100 mL with 10%$^{V}/_{V}$ HCl.

8.9.2 *100 µg/L Hg Stock Solution*—Dilute 1 mL of 10 mg/L Hg stock solution to 100 mL with 10%$^{V}/_{V}$ HCl.

8.9.3 *Working Hg Standards*—Prepare working standards of 1.0, 5.0, 10.0, and 20.0 µg/L Hg from the 100-µg/L stock solution by diluting 1, 5, 10, and 20 mL each to 100 mL with 10%$^{V}/_{V}$ HCl.

Note 1—If samples to be analyzed are less than 1.0 µg/L Hg, working standards should be prepared at 0.05, 0.1, 0.5, and 1.0 µg/L Hg from a 10-µg/L Hg standard solution.

8.9.4 *Quality Control Standard (QC)*—A quality control standard is prepared from a separate Hg standard solution. The QC standard should be prepared at a concentration of approximately one-half the calibration range.

8.10 *Glassware Cleaning Reagents*—Prior to any fieldwork, all glassware should be cleaned according to the guidelines outlined in EPA Method 29, section 5.1.1

9. Hazards

9.1 *Warning*:

9.1.1 Pressure may build up in the solution storage bottle because of a potential reaction between potassium permanganate and acid. Therefore, these bottles should not be fully filled and should be vented to relieve excess pressure and prevent explosion. Venting must be in a manner that will not allow contamination of the solution.

9.1.2 Hazards to personnel exist in the operation of the cold-vapor atomic absorption spectrophotometer. Refer to the manufacturer's instruction manual before operating the instrument.

9.1.3 Sample digestion with hot concentrated acids creates a safety problem. Observe appropriate laboratory procedures for working with concentrated acids.

9.2 *Precaution:*

9.2.1 The determination of microquantities of mercury species requires meticulous attention to detail. Good precision is generally unattainable without a high level of experience with stack-sampling procedures. Precision may be improved by knowledge of, and close adherence to, the suggestions that follow.

9.2.1.1 All glassware used in the method must be cleaned thoroughly prior to use in the field, as described in Section 8.10 of this method.

9.2.1.2 Use the same reagents and solutions in the same quantities for a group of determinations and the corresponding solution blank. When a new reagent is prepared or a new stock of filters is used, a new blank must taken and analyzed.

10. Sampling

10.1 *Preparation for Test:*

10.1.1 *Preliminary Stack Measurements*—Select the sampling site, and determine the number of sampling points, stack pressure, temperature, moisture, dry molecular weight, and range of velocity head in accordance with procedures of ASTM Test Method D 3154 or EPA Methods 1 through 4.

10.1.2 Select the correct nozzle diameter to maintain isokinetic sampling rates based on the range of velocity heads determined in 10.1.1.

10.1.3 Ensure that the proper differential pressure gauge is selected for the range of velocity heads (refer to EPA Method 2, Section 2.2).

10.1.4 It is suggested that an EPA Method 17 configuration be used; however, if an EPA Method 5 setup is to be used, then select a suitable probe length such that all traverse points can be sampled. Consider sampling from opposite sides of the stack to minimize probe length when a large duct or stack is sampled.

10.1.5 *Sampling Time and Volume*—The total sampling time for this method should be at least 2 but not more than 3 hours. Use a nozzle size that will guarantee an isokinetic gas sample volume between 1.0 dry cubic meters corrected to standard conditions (dscm) and 2.5 dscm. If traverse sampling is done (necessary for sampling at electric utilities), use the same points for sampling that were used for the velocity traverse as stated in Section 10.1.1 of this method. Each traverse point must be sampled for a minimum of 5 minutes.

11. Preparation of Apparatus

11.1 *Pretest Preparation:*

11.1.1 Weigh several 200- to 300-g portions of silica gel in airtight containers to the nearest 0.5 g. Record the total mass of the silica gel plus container on each container. Alternatively, the silica gel can be weighed directly in the impinger immediately prior to the train being assembled.

11.1.2 Desiccate the sample filters at 20° ± 5.6°C (68° ± 10°F) and ambient pressure for 24 to 36 hours, weigh at intervals of at least 6 hours to a constant mass (i.e., <0.5-mg change from previous weighing), and record results to the nearest 0.1 mg. Alternatively, the filters may be oven-dried at 105°C (220°F) for 2 to 3 hours, desiccated for 2 hours, and weighed.

11.1.3 Clean all sampling train glassware as described in Section 8.10 before each series of tests at a single source. Until the sampling train is assembled for sampling, cover all glassware openings where contamination can occur.

11.2 *Preparation of Sampling Train:*

11.2.1 Assemble the sampling train as shown in Figure 1.

11.2.2 Place 100 mL of the KCl solution (see Section 8.5.1 of this method) in each of the first, second, and third impingers, as indicated in Figure 1.

11.2.3 Place 100 mL of the HNO_3–H_2O_2 solution (Section 8.5.2 of this method) in the fourth impinger, as indicated in Figure 1.

11.2.4 Place 100 mL of the H_2SO_4–$KMnO_4$ absorbing solution (see Section 8.5.3 of this method) in each of the fifth, sixth, and seventh impingers, as indicated in Figure 1.

11.2.5 Transfer approximately 200 to 300 g of silica gel from its container to the last impinger, as indicated in Figure 1.

11.2.6 Prior to final train assembly, weigh and record the mass of each impinger. This information is required to calculate the moisture content of the sampled flue gas.

11.2.7 To ensure leak-free sampling train connections and to prevent possible sample contamination problems, use PTFE tape, PTFE-coated O-rings, or other noncontaminating material.

11.2.8 Place a weighed filter in the filter holder using a tweezer or clean disposable surgical gloves.

11.2.9 Install the selected nozzle using a noncontaminating rubber-type O-ring or equivalent when stack temperatures are less than 260°C (500°F) and an alternative gasket material when temperatures are higher. Other connecting systems, such as PTFE ferrules or ground glass joints, may also be used on the probe and nozzle.

11.2.10 Mark the probe with heat-resistant tape or by some other method to denote the proper distance into the stack or duct for each sampling point.

11.2.11 Place crushed or cubed ice around the impingers.

11.2.12 *Leak-Check Procedures*. Follow the leak-check procedures given in Section 4.1.4.1 (Pretest Leak Check), Section 4.1.4.2 (Leak Checks During the Sample Run), and Section 4.1.4.3 (Posttest Leak Checks) of EPA Method 5 or 17.

Note 2—If the flue gas temperature at the sampling location is greater than 260°C (above the temperature where PTFE or rubber-type seals can be used), the posttest leak check is determined beginning at the front end of the probe (does not include nozzle or sample filter holder for EPA Method 17).

12. Calibration and Standardization

12.1 *Sampling Train Calibration:*

12.1.1 *Probe Nozzle*—Refer to Sections 2.1.1 of either EPA Method 5 or 17.

12.1.2 *Pitot Tube*—Refer to Section 4 of EPA Method 2.

12.1.3 *Metering System*—Refer to Section 5.3 of either EPA Method 5 or 17.

12.1.4 *Probe Heater*—Refer to Section 7.1.7.1 and 7.1.7.2 of this method.

12.1.5 *Temperature Gauges*— Refer to Section 4.3 of EPA Method 2.

12.1.6 *Leak Check of the Metering System*—Refer to Section 5.6 of EPA Method 5 or Section 5.5 of EPA Method 17.

12.1.7 *Barometer*—Calibrate the barometer to be used against a mercury barometer.

12.2 *Atomic Absorption or Atomic Fluorescence Spectrometer Calibration*—Perform instrument setup and optimization according to the manufacturer's specifications. Cold-vapor generation of mercury is performed via addition of stannous chloride solution to reduce oxidized mercury to its elemental state. The mercury-laden solution is then purged with a carrier gas into the atomic absorption cell. This procedure is used to calibrate the instrument using 10% $^{V}/_{V}$ HCl as the blank along with the standards described in Section 8.9.3. Calibration is verified by analyzing the QC standard prepared according to Section 8.9.4 of this method.

13. Procedures

13.1 *Sampling Train Operation:*

13.1.1 Maintain an isokinetic sampling rate within 10% of true isokinetic. For an EPA Method 5 configuration, maintain sample filter exit gas stream temperatures and probe within ±15°C of the flue gas temperature at the sampling location. However, at no time, regardless of the sample configuration, must the sample filter, probe, or connecting umbilical cord temperature be lower than 120°C.

13.1.2 Record the data, as indicated in Figure 2, at least once at each sample point but not less than once every 5 minutes.

13.1.3 Record the dry gas meter reading at the beginning of a sampling run, the beginning and end of each sampling time increment, before and after each leak check, and when sampling is halted.

13.1.4 Level and zero the manometer. Periodically check the manometer level and zero, because it may drift during the test period.

13.1.5 Clean the port holes prior to the sampling run.

13.1.6 Remove the nozzle cap. Verify that the filter and probe heating systems are up to temperature and that the pitot tube and probe are properly positioned.

Note 3—For an EPA Method 5 configuration, prior to starting the gas flow through the system, the sample filter exit gas temperature may not be at the hot box temperature. However, if the system is set up correctly, once flow is established, the sample filter exit gas temperature will quickly come to equilibrium.

13.1.7 Start the pump. Position the nozzle at the first traverse point with the nozzle tip pointing in the direction of flow. Seal the openings around the probe and port hole to prevent unrepresentative dilution of the gas stream. Read the pitot tube manometer, start the stopwatch, open and adjust the control value until the isokinetic sampling rate is obtained (refer to Section

4.1.5 from either EPA Method 5 or 17 for information on isokinetic sampling rate computations), and maintain the isokinetic rate at all points throughout the sampling period.

13.1.8 When sampling at one traverse point has been completed, move the probe to the next traverse point as quickly as possible. Close the coarse adjust valve, and shut the pump off when transferring the probe from one sample port to another. Exclude the time required to transfer the probe from one port to another from the total sampling time.

13.1.9 Traverse the stack cross section, as required by EPA Method 1.

13.1.10 During sampling, periodically check and, if necessary, adjust the probe and filter exit sample gas temperatures, as well as the zero of the manometer.

13.1.11 Add more ice, if necessary, to maintain a temperature of <20°C (68°F) at the condenser/silica gel outlet.

13.1.12 Replace the filter assembly if the pressure drop across the filter becomes such that maintaining isokinetic sampling is no longer possible. Conduct a leak check (refer to EPA Method 5 or 17, Section 4.1.4.2) before installing a new filter assembly. The total particulate mass and determination of particle-bound mercury includes all filter assembly catches.

13.1.13 In the unlikely event depletion of $KMnO_4$ via reduction reactions with flue gas constituents other than elemental mercury occurs, it may render it impossible to sample for the desired minimum time. This problem is indicated by the complete bleaching of the purple color of the acidified permanganate solution. If the purple color is lost in the first two H_2SO_4–$KMnO_4$ impingers, then the sample must be repeated. If the gas stream is known to contain large amounts of reducing constituents (i.e., >2500 ppm SO_2) or breakthrough has occurred in previous sampling runs, then the following modification is suggested: the amount of HNO_3–H_2O_2 (10% $^V/_V$) in the fourth impinger should be doubled, and/or a second HNO_3–H_2O_2 impinger should be used to increase the oxidation capacity for reducing gas components prior to the H_2SO_4–$KMnO_4$ impingers.

13.1.14 Use a single train for the entire sample run, except when simultaneous sampling is required in two or more separate ducts or at two or more different locations within the same duct or when equipment failure necessitates a change of trains.

13.1.15 At the end of a sample run, turn off the coarse adjust valve, remove the probe and nozzle from the stack, record the final dry gas meter reading, and conduct a posttest leak check, as described in Section 4.1.4.3 of EPA Method 5. Also, leak-check the Pitot lines as described in EPA Method 2, Section 3.1. The lines must pass the leak check to validate the velocity head data.

13.1.16 Calculate percent isokinetic to determine whether the run was valid or another test run should be performed (refer to EPA Method 5 or 17).

13.2 *Sample Recovery:*

13.2.1 Allow the probe to cool before proceeding with sample recovery. When the probe can be safely handled, wipe off all external particulate matter near the tip of the probe nozzle, and place a rinsed, noncontaminating cap over the probe nozzle to prevent losing or gaining particulate matter. Do not cap the probe tip tightly while the sampling train is cooling; a vacuum can form in the filter holder, with the undesired result of drawing liquid from the impingers onto the filter.

13.2.2 Before moving the sampling train to the cleanup site, remove the probe from the sampling train, and cap the open outlet. Be careful not to lose any condensate that may be present. Cap the filter inlet where the probe was fastened. Remove the umbilical cord from the last impinger, and cap the impinger. Cap the filter holder outlet and impinger inlet. Use noncontaminating caps, such as ground-glass stoppers, plastic caps, serum caps, or PTFE tape, to close these openings.

13.2.3 Alternatively, the following procedure may be used to disassemble the train before the probe and filter holder/oven are completely cooled. Initially disconnect the filter holder outlet/impinger inlet, and loosely cap the open ends. Then disconnect the probe from the filter holder or cyclone inlet, and loosely cap the open ends. Cap the probe tip, and remove the umbilical cord as previously described.

13.2.4 Transfer the probe and filter–impinger assembly to a clean area that is protected from the wind and other potential causes of contamination or loss of sample. Inspect the train before and during disassembly, and note any abnormal conditions.

13.2.5 The impinger train sample recovery scheme is illustrated in Figure 3.

13.2.6 *Container 1 (Sample Filter)*—Carefully remove the sample filter from the filter holder so as not to lose any ash, weigh filter and ash, and place the filter in a labeled petri dish container. To handle the filter, use either acid-washed polypropylene or PTFE-coated tweezers or clean, disposable surgical gloves rinsed with water and dried. If it is necessary to fold the filter, make certain the particulate cake is inside the fold. Transfer any particulate matter or filter fibers that adhere to the filter holder gasket to the filter in the petri dish. A dry (acid-cleaned) nonmetallic bristle brush should be used to remove any remaining particulate matter. Do not use any metal-containing materials when recovering this train. Immediately cover and seal the labeled petri dish.

13.2.7 *Container 2/2a (All Rinses in Front of the Sample Filter)*

13.2.7.1 *Case 1: Includes Gravimetric Particulate Determination in Addition to Mercury*

Quantitatively recover particulate matter and any condensate from all components prior to the sample filter. A nonmetallic brush may be used for removing particulate matter. All front-half components (all components prior to the sample filter) are then rinsed with acetone as outlined in

EPA Method 5 or 17. The acetone rinse is then placed into a container (Container 2a) for which the tare weight has been recorded. Container 2a, with a ribbed watch glass over the top, is placed in a fume hood until the acetone has completely evaporated. After the front-half components have been rinsed with acetone, then rinse these components with 0.1 N HNO_3. The 0.1 N HNO_3 rinse is placed in Container 2.

13.2.7.2 *Case 2: Mercury Determination Only (No Acetone Rinse)*

Quantitatively recover particulate matter and any condensate from all components prior to the sample filter. A nonmetallic brush may be used for removing particulate matter. The front-half components are then rinsed with 0.1 N HNO_3, and this rinse is placed in Container 2.

13.2.8 *Container 3 (Impingers 1 through 3, KCl Impinger Contents and Rinses)*:

13.2.8.1 Dry the exterior surfaces of Impingers 1, 2, and 3. Then weigh and record the mass of each impinger (to the nearest 0.5 g).

13.2.8.2 Clean the filter support, the back half of the filter housing, and connecting glassware by thoroughly rinsing with 0.1 N HNO_3. Pour the rinse into a glass sample Container 3.

13.2.8.3 Carefully add small amounts of 5% $^{W}/_{V}$ $KMnO_4$ solution very slowly to each KCl impinger and gently mix the impinger solution. Continue adding $KMnO_4$ solution until a purple color is obtained. Let the impingers sit for approximately 15 minutes to ensure the purple color persists.

13.2.8.4 Pour all of the liquid from the three KCl impingers into Container 3.

13.2.8.5 Rinse the impingers and connecting glassware with 10%$^{V}/_{V}$ HNO_3. Although unlikely, if deposits remain on the impinger surfaces, remove them by doing another 10%$^{V}/_{V}$ HNO_3 rinse that has a very small amount (several drops) of 10%$^{W}/_{V}$ hydroxylamine solution added to the HNO_3 rinse solution. Rinse each of the KCl impingers with this solution until the brown stains are removed. Add these rinses to Container 3. If the solution in Container 3 becomes clear, add a small amount of the 5% $^{W}/_{V}$ $KMnO_4$ solution until a pink or slightly purple color is obtained. Check again after 90 min to ensure the purple color remains.

13.2.8.6 Perform a final rinse of the impingers and connecting glassware with 0.1 N HNO_3, and add to Container 3.

13.2.8.7 Do a final rinse of all glass components with water which is discarded.

13.2.8.8 Mark the height of the fluid level in Container 3, seal, and clearly label the contents.

13.2.9 *Container 4 (Impinger 4, HNO_3–H_2O_2 Impinger Contents and Rinses):*

13.2.9.1 Dry the exterior surfaces of Impinger 4. Then weigh and record the mass of this impinger (to the nearest 0.5 g).

13.2.9.1 Pour the HNO_3–H_2O_2 absorbing solution into sample Container 4.

13.2.9.2 Rinse the H_2O_2–HNO_3 impinger and connecting glassware a minimum of two times with 0.1 N HNO_3, and pour the rinses into Container 4. Do a final rinse with water and discard water.

13.2.10 *Container 5 (Impingers 5 through 7, H_2SO_4–$KMnO_4$ Impinger Contents and Rinses):*

13.2.10.1 Dry the exterior surfaces of Impingers 5, 6, and 7. Then weigh and record the mass of each impinger (to the nearest 0.5 g).

13.2.10.2 Pour all of the liquid from the three H_2SO_4–$KMnO_4$ impingers into a glass sample Container 5.

13.2.10.3 Rinse the H_2SO_4–$KMnO_4$ impingers and connecting glassware a minimum of two times with 0.1 N HNO_3, and pour the rinses into Container 5. A third rinse must then be done (this rinse will remove any brown stains from the surface of the impingers). This rinse consists of 0.1N HNO_3 and several drops of 10% $^{w}/_{v}$ hydroxylamine solution (either the NH_2OH/NaCl solution or the $NH_2OH{\cdot}HCl$ solution). This rinse must have enough 10% $^{w}/_{v}$ hydroxylamine solution such that the brown stains are easily removed. If they are not easily removed add several more drops of 10% $^{w}/_{v}$ hydroxylamine solution until the stains are completely gone. Add this rinse to Container 5. If the solution in Container 5 becomes clear, add small amounts of the H_2SO_4–$KMnO_4$ solution until a pink or slightly purple color is obtained.

13.2.10.4 Perform a final 0.1 N HNO_3 rinse of the impingers and connecting glassware follow by a water rinse. The 0.1 N HNO_3 rinse is added to Container 5, and the water rinse is discarded.

13.2.10.5 Mark the height of the fluid level, seal the container, and clearly label the contents.

Note 4—As stated earlier in the warning in Section 9.1.1, pressure can build up in the sample storage flask because of the potential reaction of $KMnO_4$ with acid. Do not fill the container completely, and take precautions to relieve excess pressure.

13.2.11 *Container 6 (Impinger 8, Silica Gel Impinger Contents)*:

13.2.11.1 Dry the exterior surfaces of Impinger 8. Then weigh and record the mass of this impinger (to the nearest 0.5 g).

13.2.11.2 Note the color of the indicating silica gel to determine whether it has been completely spent, and make a notation of its condition. If spent, the silica gel must be either regenerated or disposed of.

13.2.12 *Solution Blanks (Containers 7–11)*

Solution blanks are taken each time new reagents are prepared. *Note:* The amount of solution collected for the blanks stated below is a suggested volume.

13.2.12.1 *Container 7 (0.1 N HNO_3 Blank)*—Place 50 mL of the 0.1 N HNO_3 solution used in the sample recovery process into a properly labeled container. Seal the container.

13.2.12.2 *Container 8 (1 N KCl Blank)*—Place 50 mL of the 1 N KCl solution used as the impinger solution into a properly labeled container. Seal the container.

13.2.12.3 *Container 9 (5%$^V/_V$ HNO_3–10%$^V/_V$ H_2O_2 Blank)*—Place 50 mL of the HNO_3–H_2O_2 solution used as the nitric acid impinger reagent into a properly labeled container. Seal the container.

13.2.12.4 *Container 10 (H_2SO_4–$KMnO_4$ Blank)*—Place 50 mL of the H_2SO_4–$KMnO_4$ solution used as the impinger solution in the sample recovery process into a properly labeled container. Refer to **Note 4** in Section 13.2.10.5 of this method.

13.2.12.5 *Container 11 (10% $^W/_V$ Hydroxylamine Solution)*—Place 100 mL of hydroxylamine solution into a properly labeled sample container. Seal the container.

13.2.13 *Container 12 (Sample Filter Blank)*—Once during each field test, place into a properly labeled petri dish three unused blank filters from the same lot as the sampling filters. Seal the petri dish.

13.2.14 After all of the samples have been recovered, they must be analyzed within 45 days.

13.2.15 After all impingers and connectors have been properly rinsed and the solutions recovered, the glassware should be cleaned according to the procedures in Section 8.10 or triple-rinsed with 10%$^V/_V$ HNO_3 followed by a rinsing with water. If a new source is to be sampled or if there are any brown stains on the glassware, then the glassware must be cleaned according to procedures in Section 8.10 of this method. If multiple sites are to sampled during a single mobilization, an exception to this procedure will be allowed. In this case, a triple rinsing of the glassware with 10%$^V/_V$ HNO_3 solution followed by a water rinse prior to sampling can be used as an alternative to the procedures in Section 8.10. However, if there are any brown stains on the glassware, then the glassware must be cleaned according to procedures in Section 8.10 of this method.

13.3 *Sample Preparation:*

13.3.1 *Ash Sample (Containers 1 and 2)*

13.3.1.1 *Case 1: Includes Gravimetric Particulate Determination in Addition to Mercury*—The gravimetric particulate loading is determined from the mass of the ash on the filter (Container 1) and the residual particulate from the acetone rinse (Container 2a), as outlined in EPA Method 5 or 17. If a large amount of ash is on the filter, carefully remove the ash to create a raw ash sample from which a representative weighed aliquot can be taken for digestion. If the mass of ash collected on the filter is small (less than 0.5 g), digest the entire filter along with the ash. Dissolve the residual particulate from Container 2a using concentrated HNO_3. This solution is then added to Container 2 (0.1 N HNO_3 probe rinse). The ash material from Container 1 is then digested using the procedures described in Section 13.3.2 of this method. The same procedure is used to determine the mercury on the sample filter blank.

Use a modification of EPA SW 846 7470 to digest the sample in Container 2 prior to analysis. The main modification is that the volumes of reagents and sample have been reduced tenfold to reduce waste. This reduction in reagent volume is acceptable because modern dedicated mercury analyzers do not require the large volumes that previous manual methods required. Transfer a 10-mL aliquot of the sample to a digestion tube with a screw cap.

13.3.1.2 *Case 2: Mercury Determination Only*—The same procedures are followed as described previously in Section 13.3.1.1 with the exception that there is no Container 2a.

13.3.2 *Ash Digestion*—Accomplish the complete dissolution of ash by one of the following methods or an equivalent alternative method. The following methods are for the dissolution of inorganic samples, such as ash or sediments, when an analysis of trace elements including mercury is done.

13.3.2.1 *Microwave Digestion*—The use of this method assumes proper training in microwave digestion techniques. In addition, this method is tailored for a CEM (continuous emission monitor) microwave digestion system. A 0.5-g ash sample, accurately weighed to 0.0001 g, is placed in a PTFE microwave digestion vessel with 3 mL of concentrated HF, 3 mL of concentrated HNO_3, and 3 mL of concentrated HCl. The vessel is sealed and placed in the microwave (along with other vessels). The vessels are slowly heated to a pressure of 347 kPa (50 psi), which is held for 5 minutes, followed by heating to a pressure of 550 kPa (80 psi), which is held for 20 minutes. The vessels are allowed to cool to room temperature before venting. 15 mL of 4%$^{W}/_{V}$ boric acid is added to each vessel. The vessels are sealed and placed in the microwave again. The vessels are slowly heated back to a pressure of 347 kPa (50 psi) and held for 10 minutes. The vessels are again allowed to cool to room temperature before venting. The contents of each vessel are quantitatively transferred to a 50-mL PMP or polypropylene (PP) volumetric flask and diluted; note that care must be taken in adding water to a strong acid solution.

13.3.2.2 *Conventional Digestion*—The use of this method assumes proper training in PTFE bomb digestion techniques. Place a 0.5-g ash sample, accurately weighed to 0.0001 g, in a PTFE digestion vessel with 7 mL of concentrated HF and 5 mL of aqua regia. Seal the vessel, and place it in an oven or water bath at 90°C for a minimum of 8 hours (these may be heated overnight). Cool the vessel to room temperature before venting. Add 3.5 g of boric acid and 40 mL of water to each vessel. Seal the vessels, and place them in the oven or water bath for an additional 1 hour. Cool the vessels again to room temperature before venting. Quantitatively transfer the contents of each vessel to a 100-mL PMP, PP, or glass volumetric flask and dilute. Note that care must be taken in adding water to a strong acid solution.

13.3.3 *Preparation of Aqueous KCl Impinger Solution (Containers 3 and 8)*—Dilute sample in a 500-mL volumetric flask to volume with water, and mix. Use a modification of EPA SW 846 7470 to digest the sample prior to analysis. The main modification is that the volumes of reagents and sample have been reduced tenfold to reduce waste. This reduction in reagent volume is acceptable because modern dedicated mercury analyzers do not require the large volumes that previous manual methods required. Transfer a 10-mL aliquot of the sample to a digestion tube with a screw cap. Add 0.5 mL of concentrated H_2SO_4, 0.25 mL of concentrated HNO_3, and 1.5 mL of 5%$^W/_V$ $KMnO_4$ solution. Mix the solution, and allow it to stand for 15 minutes. Add 0.75 mL of 5%$^W/_V$ $K_2S_2O_8$ solution, and loosely cap the tube. Place the tube in a dry block heater or water bath equipped with a temperature probe, and heat to 95°C. Do not allow the temperature to exceed 95°C. Hold the sample at 95°C for 2 hours before allowing it to cool to room temperature. The purple color from the added $KMnO_4$ solution must remain throughout the digestion. Clearing of the solution during the heating indicates the depletion of $KMnO_4$. If the solution goes clear add more $KMnO_4$ to the sample until a purple color persists. Prior to analysis, add 1 mL of 10%$^W/_V$ hydroxylamine sulfate solution to the sample. The sample solution should remain clear after addition of hydroxylamine sulfate. Record the volumes of the solution additions used in the preparation procedure and adjust the DF factor in equation 9 as necessary.

13.3.4 *Preparation of HNO_3–H_2O_2 Impinger Solution (Containers 4 and 9)*—Dilute sample in a 250-mL volumetric flask to volume with water, and mix. Treat the sample with a modified version of EPA SW 846 7470. Modifications to the method are necessary to properly treat the H_2O_2-containing impinger solution before the analysis with CVAAS. The modifications include the addition of HCl, the use of an ice bath during the $KMnO_4$ addition, and the slow addition of the $KMnO_4$. Transfer a 5-mL aliquot of the sample to a digestion tube with a screw cap. Add 0.25 mL of concentrated HCl, 0.25 mL of concentrated H_2SO_4, place the tube in an ice bath, and allow it to cool for 15 minutes. The destruction of H_2O_2 is accomplished by slow addition of saturated $KMnO_4$ solution in 0.25-mL increments along the inside of the digestion tube. The violence of this reaction requires careful, slow addition of the $KMnO_4$ for safety reasons and to avoid loss of analyte. Cool the sample for 15 minutes in between each addition, and mix the sample prior to each addition. After the first five additions, increase the increments to 0.5 mL. Carry out the addition of $KMnO_4$ until the solution remains purple, indicating complete reaction of the H_2O_2. Record the volume of saturated $KMnO_4$ solution added to the sample. Add 0.75 mL of 5%$^W/_V$ $K_2S_2O_8$ solution to the sample, and then cap the tube loosely. Place the tubes in a dry block heater or water bath equipped with a temperature probe, and heat to 95°C. Do not allow the temperature to exceed 95°C. Maintain the sample at 95°C for 2 hours before allowing it to cool to room temperature. Note that the purple color due to $KMnO_4$ must remain throughout the digestion. Clearing of the solution during the heating indicates the depletion of $KMnO_4$. Before doing the analysis, add 1mL 10%$^{W}/_{V}$ of hydroxylamine sulfate solution to the sample. The sample should then become clear. Record the volumes of the solution additions used in the preparation procedure and adjust the DF factor in equation 13 as necessary.

13.3.5 *Preparation of H_2SO_4–$KMnO_4$ Impinger Solution (Containers 5 and 10)*—Prepare the entire solution immediately prior to analysis. Dissolve by incrementally adding approximately 500 mg of solid hydroxylamine sulfate into the sample until a clear, colorless solution persists. (This is to ensure that a representative aliquot sample can be taken and that any mercury contained in the manganese dioxide that forms from the permanganate solution will be removed). Add the hydroxylamine slowly because of the violence of this reaction. Dilute the sample in a 500-mL volumetric flask to volume with water, and mix. Transfer a 10-mL aliquot of the sample to a digestion tube with a screw cap. Add 0.75 mL of 5%$^{W}/_{V}$ $K_2S_2O_8$ solution and 0.5mL of concentrated HNO_3, and loosely cap the tube. Place the tube in a dry block heater or water bath equipped with a temperature probe, and heat to 95°C. Do not allow the temperature to exceed 95°C. Hold the sample at 95°C for 2 hours before allowing it to cool to room temperature. The purple color of the $KMnO_4$ solution must remain throughout the digestion. Clearing of the solution during the heating indicates the depletion of $KMnO_4$. Prior to analysis, add 1 mL of 10%$^{W}/_{V}$ of hydroxylamine sulfate solution to the sample. The sample solution should remain clear after addition of hydroxylamine sulfate. Record the volumes of the solution additions used in the preparation procedure and adjust the DF factor in equation 12 as necessary.

13.3.6 *Simplification of the Digestion*—If an acetone rinse was not used for gravimetric particulate determination or it is very clear, there is insignificant organic material present in the sampled gas stream; then the digestion procedure for the HNO_3–H_2O_2 and H_2SO_4–$KMnO_4$ impinger solutions may be simplified by omitting the persulfate digest. The persulfate digest is performed for the purpose of oxidizing certain organics. Because this method is specific to coal combustion systems where organic compounds are usually insignificant,[8] this digest may be omitted because the H_2O_2 is sufficient to oxidize most compounds. The decision to omit this procedure should be made based on the gas stream being sampled and/or verification that organics resistant to H_2O_2 oxidation are not present. If unsure whether organics are present or if an acetone rinse has been used, then the total digestion procedure is required.

13.3.6.1 *Simplified Procedure for the Preparation of HNO_3–H_2O_2 Impinger Solution*—If the simplified procedure can be used for the HNO_3–H_2O_2 impinger solution, the concentrated H_2SO_4 and 5%$^{W}/_{V}$ $K_2S_2O_8$ are not added to the HNO_3–H_2O_2 aliquot sample. Also it is not necessary to heat the sample to 95°C followed by 2 hours of cooling. However, it is still necessary that the concentrated HCl be added to the solution.

[8] "A Comprehensive Assessment of Toxic Emissions from Coal-Fired Power Plants: Phase I Results from the U.S. Department of Energy Study," Prepared for the U.S. Department of Energy Federal Energy Technology Center, Contract No. DE-FC21-93MC30097, Energy & Environmental Research Center, University of North Dakota, Grand Forks, ND, 1996.

Just before doing the analysis, add 1mL 10%$^W/_V$ of hydroxylamine solution to the sample. The sample should then become clear. If the simplified procedure is used, $V(K_2S_2O_8)$ and $V(H_2SO_4)$ are zero when calculating DF in Equation 12 Section 15.

13.3.6.2 *Simplified procedure for the Preparation of H_2SO_4–$KMnO_4$ Impinger Solution*—If the simplified procedure can be used for the H_2SO_4–$KMnO_4$ impinger solution, the concentrated HNO_3 and 5%$^W/_V$ $K_2S_2O_8$ are not added to the H_2SO_4–$KMnO_4$ aliquot sample. Also it is not necessary to heat the sample to 95°C followed by 2 hours of cooling. Just before doing the analysis, add 1mL 10%$^W/_V$ of hydroxylamine solution to the sample. The sample should then become clear. If the simplified procedure is used, $V(K_2S_2O_8)$ and $V(HNO_3)$ are zero when calculating DF in Equation 13 Section 15.

13.3.7 *Reagent blanks (Containers 8 through 10)*—These samples are not diluted prior to taking an aliquot. Once an aliquot is taken the preparation steps for each of the solutions (as well as the mercury concentration calculations) are the same as described above. These are Section 13.3.3 for the aqueous KCl reagent blank, Section 13.3.4 for the HNO_3–H_2O_2 reagent blank, and Section 13.3.6.2 for the H_2SO_4–$KMnO_4$ reagent blank.

13.3.8 *0.1 N HNO_3 and 10%$^W/_V$ Hydroxylamine Rinse Solutions* (*Containers 7 and 11)*—These solutions can be analyzed directly for mercury without any preparation steps.

13.4 *Sample Analysis*—Analyze all of the prepared solutions by CVAAS or CVAFS following the guidelines specified by the instrument manufacturer.

13.4.1 *QA/QC*—For this method, it is important that both the sampling team and analytical people be very well trained in the procedures. This is a complicated method that requires a high-level of sampling and analytical experience. For the sampling portion of the QA/QC procedure, both solution and field blanks are required. It should be noted that if high-quality reagents are used and care is taken in their preparation and in the train assembly, there should be little, if any, mercury measured in either the solution or field blanks.

As stated in Section 13.2.12 of this method, solution blanks will be taken and analyzed every time a new batch of solution is prepared. If mercury is detected in these solution blanks, the concentration is subtracted from the measured sample results. The maximum amount that can be subtracted is 10% of the measured result or 10 times the detection limit of the instrument which ever is lower. If the solution blanks are greater than 10% the data must be flagged as suspect.

A field blank is performed by assembling an impinger train, transporting it to the sampling location during the sampling period, and recovering it as a regular sample. These data are used to ensure that there is no contamination as a result of the sampling activities. A minimum of one field blank at each sampling location must be completed for each test site. Any mercury detected in the field blanks cannot be subtracted from the results. Whether or not the mercury detected in the field blanks is significant is determined based on the QA/QC procedures established prior to the testing. At a minimum, if field blanks exceed 30% of the measured value at the corresponding location, the data must be flagged as suspect.

The QA/QC for the analytical portion of this method is that every sample, after it has been prepared, is to be analyzed in duplicate with every tenth sample analyzed in triplicate. These results must be within 10% of each other. If this is not the case, then the instrument must be recalibrated and the samples reanalyzed. In addition, after every ten samples, a known spike sample must be analyzed. For the ash samples, a certified reference ash sample (may be purchased from NIST) is to be digested and analyzed at least once during the test program. It is also suggested that the QA/QC procedures developed for a test program include submitting, on occasion, spiked mercury samples to the analytical laboratory by either the prime contractor if different from the laboratory or an independent organization.

14. Flue Gas Calculations

14.1 *Dry Gas Volume*—Calculate the dry gas sample volume, $V_{m(std)}$, at standard conditions using Equation 1.

$$V_{m(std)} = V_m Y \left(\frac{T_{std}}{T_m}\right) \left[\frac{P_{bar} + \Delta H}{P_{std}}\right] = K_1 V_m Y \frac{P_{bar} + \Delta H}{T_m} \qquad \text{[Eq. 1]}$$

where:

- P_{bar} = barometric pressure at the sampling site, kPa (in. Hg)
- P_{std} = standard absolute pressure, 101.3 kPa (29.92 in. Hg)
- T_m = absolute average dry gas meter temperature (refer to Figure 2), K (°R)
- T_{std} = standard absolute temperature, 293 K (528°R)
- V_m = volume of gas sample as measured by dry gas meter, dcm (dscf)
- $V_{m(std)}$ = volume of gas sample measured by the dry gas meter, corrected to standard conditions, dscm (dscf)
- Y = dry gas meter calibration factor
- ΔH = average pressure differential across the orifice meter (refer to Figure 2), kPa (in. Hg)
- K_1 = 2.894 K/kPa (17.64°R/in. Hg)

Note 5—Equation 1 can be used as written unless the leakage rate observed during any of the mandatory leak checks (i.e., leak checks conducted prior to component changes or following the test) exceeds the maximum acceptable leakage rate, L_a, equal to 0.00057 m^3/min (0.02 cfm) or 4% of the average sampling rate, whichever is less. If the leakage rate observed during the posttest leak check, L_p, or an individual leakage rate observed during the leak check conducted prior to the "ith" component change (I = 1, 2, 3, . . .n), L_i, exceeds L_a, then Equation 1 must be modified as follows:

(a) **Case I**. No component changes made during sampling run. In this case, replace V_m with the expression:

$$[V_m - (L_p - L_a)\theta]$$

where:

L_p = leakage rate observed during the posttest leak check, m^3/min (cfm)

L_a = maximum acceptable leakage rate for either a pretest leak check or for a leak check following a component change—equal to 0.00057 m^3/min (0.02 cfm) or 4% of the average sampling rate, whichever is less

θ = total sampling time, min

(b) **Case II**. One or more component changes made during the sampling run. In this case, replace V_m with the expression:

$$\left[V_m - (L_1 - L_a)\theta_1 - \sum_{i=1}^{n} (L_i - L_a)\theta_i - (L_p - L_a)\theta_p \right]$$

where:

θ_i = sampling time interval, from the beginning of a run until the first component change, min

and substitute only for those leakage rates (L_i or L_p) that exceed L_a.

14.2 *Volume of Water Vapor*—Calculate the volume of water vapor of the stack gas using Equation 2.

$$V_{w(std)} = \frac{W_{lc}\ R\ T_{std}}{M_w\ P_{std}} = K_2\ W_{lc} \qquad \text{[Eq. 2]}$$

where:

M_w = molecular weight of water, 18.0 g/g-mole (18.0 lb/lb-mole)

R = ideal gas constant, 0.008314 kPa-m^3/K-g-mole (21.85 in. Hg-ft^3/°R-lb-mole)

W_{lc} = total mass of liquid collected in impingers and silica gel (refer to Figure 2), g

$V_{w(std)}$ = volume of water vapor in the gas sample, corrected to standard conditions, scm (scf)

K_2 = 0.001336 m^3/mL (0.04707 ft^3/mL)

14.3 *Volume of Moisture*—Calculate the moisture content, B_{ws}, of the stack gas using Equation 3.

$$B_{ws} = \frac{V_{w(std)}}{V_{m(std)} + V_{w(std)}} \qquad \text{[Eq. 3]}$$

where:

B_{ws} = water vapor in the gas stream, proportion by volume

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15. Calculations for Particle-Bound, Oxidized, Elemental, and Total Mercury Concentrations:

15.1 *Particle-Bound Mercury*

15.1.1 *Case 1: Amount of Ash on the Filter is Greater Than 0.5 g*—Calculate the concentration of mercury in µg/g in the ash sample (Hg_{ash}) using Equation 4:

$$Hg_{ash}\text{, µg/g} = (IR)(DF) \qquad [Eq. 4]$$

where:
IR = instrument reading, µg/L
DF = dilution factor = (total digested volume, L)/(mass of ash digested, g)

Calculate the amount of mercury in the probe rinse (Hg_{pr}, Container 2) in µg using Equation 5:

$$Hg_{pr}\text{, µg} = (IR)(V_1) \qquad [Eq. 5]$$

where:
IR = instrument reading, µg/L
V_1 = total volume of probe rinse sample from which sample aliquot was taken, L

Equation 5 assumes no preparation steps are needed prior to analyzing the probe rinse for mercury using CVAA. Although not required, a persulfate digest can be done on the probe rinse sample as discussed in section 13.3.3. If the persulfate digest is done equation 5 becomes Hg_{pr}, µg = $(IR)(V_1)(DF)$ where DF is the same as equation 9.

There is no filter blank subtraction when >0.5 g of ash are collected on the sample filter or thimble.

The total amount of particle-bound mercury (Hg_{tp}) is then determined using Equation 6:

$$\text{Hg (particle), µg} = (Hg_{ash})(W_{ash}) + Hg_{pr} \qquad [Eq. 6]$$

where:
W_{ash} = the total mass of ash on filter, g

The concentration of particle-bound mercury (µg/dscm) in the gas stream is then determined using Equation 7:

$$Hg^{tp}\text{, µg/dscm} = \text{Hg (particle)}/V_{m(std)} \qquad [Eq. 7]$$

where:
$V_{m(std)}$ = is the total volume of dry gas sampled at standard (normal) conditions, dscm

15.1.2 *Case 2: Amount of Ash on the Filter is Less Than 0.5 g*—The calculation is the same as in Case 1 except the entire sample (ash and filter) is digested; therefore, DF in Equation 4 is defined only by the total digested volume. In addition a filter blank is subtracted as calculated in Equation 8.

$$Hg_{fb},\ \mu g = (IR)(V_2) \qquad [Eq.\ 8]$$

where:
IR = instrument reading, µg/L
V_2 = total volume of sample filter blank digest, L

Equation 7 for Case 2 then becomes: Hg (particle), $\mu g = (Hg_{ash})(W_{ash}) - Hg_{fb} + Hg_{pr}$

15.2 *Oxidized Mercury*

15.2.1 *KCl Solution (Impingers 1–3)*—Calculate the concentration of mercury in µg/L in the KCl impinger solutions using Equation 9:

$$Hg_{KCl},\ \mu g/L = (IR)(DF) \qquad [Eq.\ 9]$$

where:
IR = instrument reading, µg/L
DF = dilution factor, $\dfrac{V_D + V(H_2SO_4) + V(HNO_3) + V(KMnO_4) + V(K_2S_2O_8) + V(NH_2OH)}{V_D}$
V_D = total digested volume, 10 mL
$V(H_2SO_4)$ = volume of added concentrated H_2SO_4, 0.5 mL
$V(HNO_3)$ = volume of added concentrated HNO_3, 0.5 mL
$V(KMnO_4)$ = volume of added 5% $^W/_V$ $KMnO_4$, 1.5 mL
$V(K_2S_2O_8)$ = volume of added 5% $^W/_V$ $K_2S_2O_4$, 0.75 mL
$V(NH_2OH)$ = volume of added 10% $^W/_V$ hydroxylamine sulfate, 1.0 mL

The concentration of mercury in the KCl solution blank is calculated in the same way.

15.2.2 *Total Oxidized Mercury (Hg_O)*—is defined by method as the mercury measured in the KCl sample minus the mercury measured in the KCl solution blanks, as shown in Equation 10:

$$Hg_O,\ \mu g = (Hg_{KCl})(V_3) - (Hg_{Ob})(V_4) \qquad [Eq.\ 10]$$

where:
Hg_{KCl} = Mercury concentration measured in KCl aliquot, µg/L
V_3 = Total volume of aqueous KCl from which sample aliquot was taken, L
Hg_{Ob} = Mercury concentration measured in KCl solution blank aliquot, µg/L
V_4 = Volume of aqueous KCl originally charged to the impingers, L

The concentration of Hg^{2+} (µg/dscm) in the gas stream is then determined using Equation 11:

$$Hg^{2+}, \mu g/dscm = Hg_O/V_{m(std)} \qquad [Eq. 11]$$

where:
$V_{m(std)}$ is the total volume of dry gas sampled at standard conditions, dscm

15.3 *Elemental Mercury*

15.3.1 *HNO_3–H_2O_2 Solution (Impinger 4)*—Calculate the concentration of mercury in µg/L in the HNO_3–H_2O_2 impinger solution using Equation 12:

$$Hg_{H2O2}, \mu g/L = (IR)(DF) \qquad [Eq. 12]$$

where:

IR = instrument reading, µg/L

DF = dilution factor, $\dfrac{V_D + V(HCl) + \mathbf{V(H_2SO_4)} + V(KMnO_4) + V(K_2S_2O_8) + V(NH_2OH)}{V_D}$

V_D = total digested volume, 5 mL

V(HCl) = volume of added concentrated HCl, 0.25 mL

$V(H_2SO_4)$ = volume of added concentrated H_2SO_4, 0.5 mL

$V(KMnO_4)$ = volume of added saturated $KMnO_4$, mL (volume need to turn sample to a purple color)

$V(K_2S_2O_8)$ = volume of added 5%$^W/_V$ $K_2S_2O_4$, 0.75 mL (if used)

$V(NH_2OH$ = volume of added 10%$^W/_V$ hydroxylamine sulfate, 1.0 mL

The concentration of mercury in the HNO_3–H_2O_2 solution blank is calculated in the same way.

15.3.2 *H_2SO_4–$KMnO_4$ Solution (Impingers 5–7)*—Calculate the concentration of mercury in µg/L in the H_2SO_4–$KMnO_4$ impinger solutions using Equation 13:

$$Mercury, \mu g/L = (IR)(DF) \qquad [Eq. 13]$$

where:

DF = dilution factor, $\dfrac{V_D + \mathbf{V(HNO_3)} + V(K_2S_2O_8) + \mathbf{V(NH_2OH)}}{V_D}$

IR = instrument reading, µg/L

V_D = total digested volume, 5 mL

$V(HNO_3)$ = volume of added concentrated HNO_3, 0.5 mL

$V(K_2S_2O_8)$ = volume of added 5%$^W/_V$ $K_2S_2O_4$, 0.75 mL

The concentration of mercury in the H_2SO_4–$KMnO_4$ solution blank is calculated in the same way.

15.3.3 *Total Elemental Mercury (Hg_E)*—is defined by method as the mercury measured in the H_2SO_4–$KMnO_4$ impingers plus the mercury in the HNO_3–H_2O_2 impingers minus the solution blanks as shown in Equation 14:

$$Hg_E,\ \mu g = (Hg_{H2O2})(V_4) - (Hg_{Eb1})(V_5) + (Hg_{KMnO4})(V_6) - (H_{Eb2})(V_7) \qquad \text{[Eq. 14]}$$

where:
Hg_{H2O2} = Mercury concentration measured in HNO_3–H_2O_2 aliquot, µg/L
V_4 = Total volume of aqueous HNO_3–H_2O_2 from which sample aliquot was taken, L
V_5 = Volume of aqueous HNO_3–H_2O_2 originally charged to the impinger, L
Hg_{Eb1} = Mercury concentration measured in HNO_3–H_2O_2 solution blank aliquot, µg/L
Hg_{KMnO4} = Mercury concentration measured in H_2SO_4–$KMnO_4$ aliquot, µg/L
V_6 = Total volume of aqueous H_2SO_4–$KMnO_4$ from which sample aliquot was taken, L
V_7 = Volume of aqueous H_2SO_4–$KMnO_4$ originally charged to the impingers, L
Hg_{Eb2} = Mercury concentration measured in H_2SO_4–$KMnO_4$ solution blank aliquot, µg/L

The concentration of Hg^{2+} (µg/dscm) in the gas stream is then determined using Equation 15:

$$Hg^0,\ \mu g/dscm = Hg_E/V_{m(std)} \qquad \text{[Eq. 15]}$$

where:
$V_{m(std)}$ is the total volume of dry gas sampled at standard conditions, dscm

15.4 *Total Mercury*—Is defined by the method as the sum of the particulate bound mercury, oxidized mercury, and elemental mercury as shown in Equation 16:

$$Hg(total),\ \mu g/dscm = Hg^{tp} + Hg^{2+} + Hg^0 \qquad \text{[Eq. 16]}$$

16. Precision and Bias

16.1 *Precision*

16.1.1 Formal evaluation of the Ontario Hydro method was completed with dynamic spiking of Hg^0 and $HgCl_2$ into a flue gas stream.[9] The results are shown in Table 1. The relative standard deviation for gaseous elemental mercury and oxidized mercury was found to be less than 11% for mercury concentrations greater than 3 µg/Nm^3 and less than 34% for mercury concentrations less than 3 µg/Nm^3. In all cases, the laboratory bias for these tests based on a calculated correction factor was not statistically significant. These values were within the acceptable range, based on the criteria established in EPA Method 301 (% RSD less than 50%).

[9] EPRI. "Evaluation of Flue Gas Mercury Speciation Methods," EPRI TR-108988, Electric Power Research Institute, Palo Alto, CA, Dec. 1997.

16.1.2 The precision of particle-bound, oxidized, and elemental mercury sampling method data is influenced by many factors: flue gas concentration, source, procedural, and equipment variables. Strict adherence to the method is necessary to reduce the effect of these variables. Failure to assure a leak-free system, failure to accurately calibrate all indicated system components, failure to select a proper sampling location, failure to thoroughly clean all glassware, and failure to follow prescribed sample recovery, preparation, and analysis procedures can seriously affect the precision of the results.

16.2 *Bias*

16.2.1 Gaseous mercury species in flue gases that are capable of interacting with fly ash particles collected in the front half of the sampling train can produce a positive particle-bound mercury bias.

16.2.2 Particle-bound mercury existing in the flue gas may vaporize after collection in the front half of the sampling train because of continued exposure to the flue gas sample stream and reduced pressures during the sampling period. Such vaporization would result in a negative particle-bound mercury bias.

Table 1

Results from Formal EPA Method 301 Evaluation Tests for the Ontario Hydro Method*

	Total Vapor-Phase Mercury			**Oxidized Mercury**			**Elemental Mercury**		
Ontario Hydro Method**	Mean, µg/Nm^3	Std. Dev.	RSD, %	Mean, µg/Nm^3	Std. Dev.	RSD, %	Mean, µg/Nm^3	Std. Dev.	RSD, %
Baseline	23.35	2.05	8.79	21.24	2.13	10.02	2.11	0.65	30.69
Hg^0 Spike (15.0 µg/Nm^3)	38.89	2.00	5.13	23.32	2.08	8.94	15.57	1.09	6.97
$HgCl_2$ Spike (19.9 µg/Nm^3)	42.88	2.67	6.23	40.22	2.87	7.14	2.66	0.89	33.31

* For each mean result, there were 12 replicate samples (four quadtrains)

** The correction factor in all cases was not statically significant and is not shown.

17. Keywords—Air toxics, mercury, sampling, speciation

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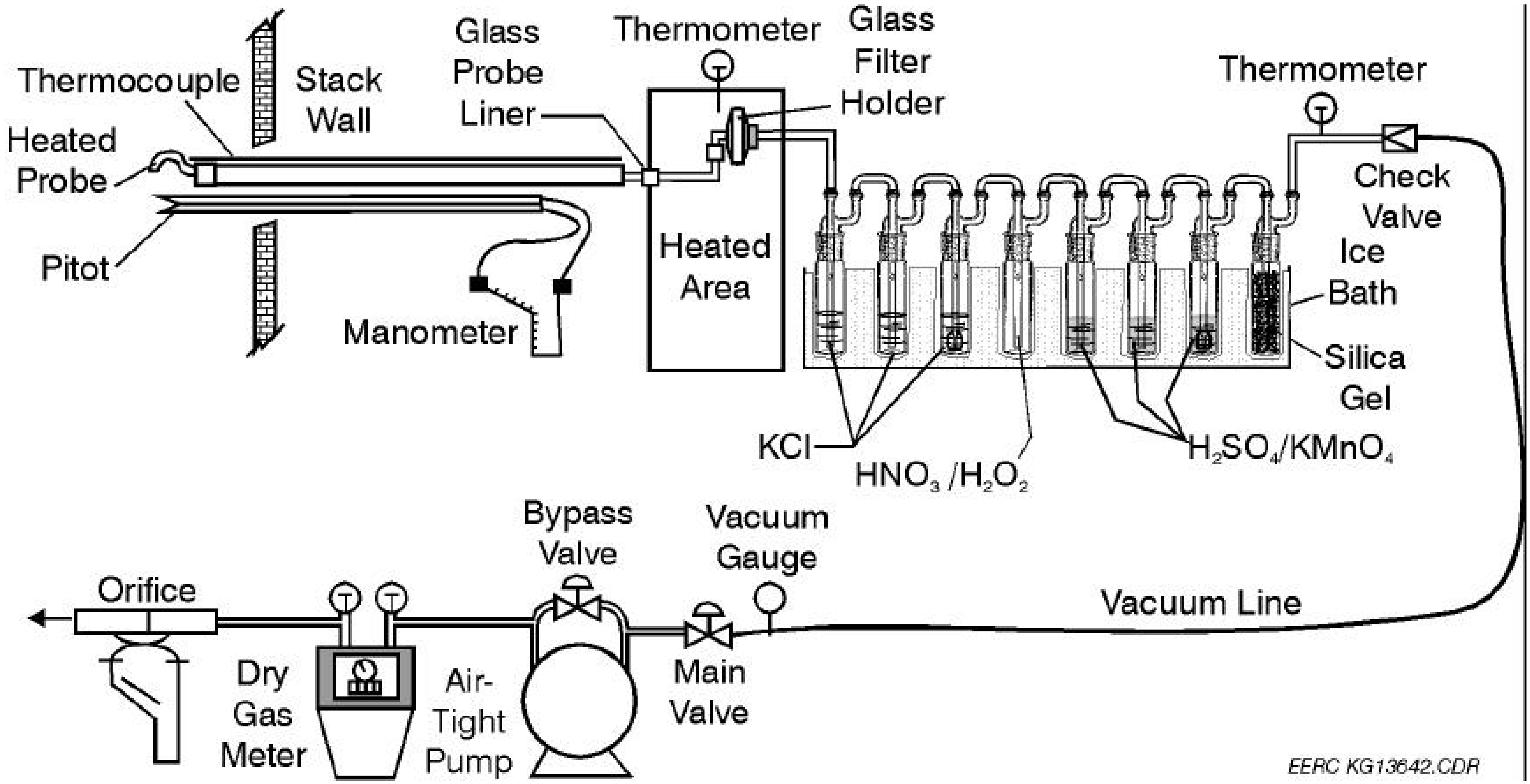

FIG. 1. Schematic of Mercury-Sampling Train in the Method 5 Configuration

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Plant..
Location...
Operator...
Date..
Run No. ....
Sample Box No. ....
Meter Box No. ....
Meter ΔH @ (kPa)..
C factor...
Pitot tube coefficient, C_p ....

Schematic of Stack Cross Section

Ambient Temperature °C (°F) ....
Barometric Pressure kPa (in. Hg).................................
Assumed Moisture, % ....
Probe Length, m (ft) ....
Nozzle Identification No. ....
Average Calibrated Nozzle Diameter, cm (in.) ....
Probe Heater Setting °C (°F) ....
Leak Rate, m^3/min (cfm) ....
Static Pressure, kPa (in. Hg) ....
Filter No. ....

Traverse Point Number	Sampling Time min	Vacuum kPa (in. Hg)	Stack Temp. (T_s), °C (°F)	Velocity Head (ΔP_s) kPa (in. H_2O)	Pressure Differential kPa (in. H_2O)	Gas Sample Volume m^3 (ft^3)	Gas Sample Temp. at Dry Gas Meter		Filter Exit Temp. °C (°F)	Probe Exit Temp. °C (°F)	Final Impinger Exit Temp. °C (°F)
							Inlet °C (°F)	Outlet °C (°F)			
Total											
Average											

FIG. 2. Mercury-Sampling Field Data Report

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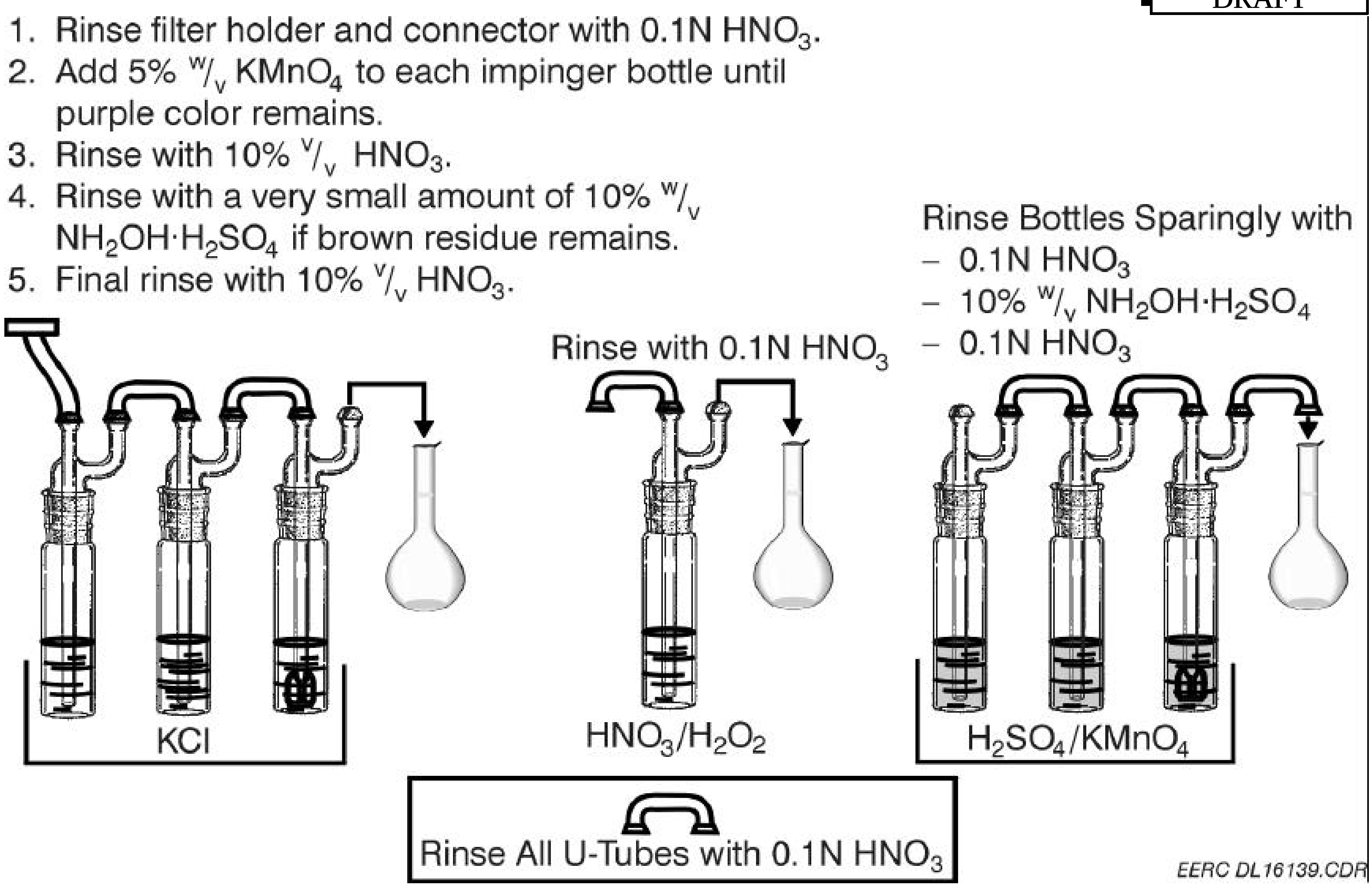

FIG. 3. Sample Recovery Scheme for the Mercury-Impinger Train

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(2) EPA Methods 6010, 6020, 7000, 7041, 7060, 7131, 7421, 7470, 7740, and 7841, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods*. SW-846, Third Edition. September 1988. Office of Solid Waste and Emergency Response, U. S. Environmental Protection Agency, Washington, D.C. 20460.

(3) EPA Methods 1 through 5, *Code of Federal Regulations*, Title 40, Part 60, Appendix A, July 1, 1991.

(4) EPA Method 101A, *Code of Federal Regulations*, Title 40, Part 61, Appendix B, July 1, 1991.

(5) EPA Method 29, *Emission Measurement Technical Information Center*, EMTIC TM-029, April 25, 1996.

(6) U.S. Environmental Protection Agency "Method 301 − Field Validation of Pollutant Measurement Method from Various Waste Media," In *Code of Federal Regulations*, Title 40, Parts 61 to 80. Washington, DC, USA, Office of the Federal Register, Part 63, Appendix A, pp 324−331, July 1993.

Appendix C: Air Compliance Test Data

Engineering Performance Stack Emission Test Report

Determination of Elemental, Oxidized, Particle-Bound, and Total Mercury Emissions

Electro-Catalyitc Oxidation Process

EPA Methods 1, 2, 3B, 4, and Preliminary Test Method PRE3 (Ontario Hydro)

Powerspan Corp.
Shadyside, Ohio

Date Conducted: May 8-10, 2002
Job Number: 020301

Prepared by:

Air Compliance Testing, Inc.
PO Box 41156
Cleveland OH 44141-0156
Phone: (800) EPA-AIR1 (372-2471)

Report Date: June 10, 2002

Air Compliance Testing, Inc.
PO Box 41156, Cleveland OH 44141
Phone: (800) EPA-AIR1 (372-2471)

June 10, 2002

Mathew Loomis
Project Coordinator
Powerspan Corp.
PO Box 219
New Durham, NH 03855

Dear Mathew:

The following report provides the results of the performance (non-compliance) emission testing conducted on May 8-10, 2002. These results are a product of the EPA Stationary Source Sampling Methods listed in 40 CFR Part 60 Appendix A abbreviated in their application in order to reduce any unnecessary costs without sacrificing accuracy.

The results of this test are intended to be used for applications such as stack emissions inventory data gathering, process and air pollution control equipment optimization studies, and pre-compliance emission level studies. Air Compliance Testing does not recommend the use of this performance test data for demonstration to the EPA of compliance with an applicable emission limit or standard such as those that are contained in an operating or installation permit. Air Compliance Testing does, however, stand behind the accuracy of the results of this test and ensures acceptable repeatability of these results under identical process operating conditions.

Please do not hesitate to call if you have any questions or concerns about these test results or any other emission testing related topics. On behalf of Air Compliance Testing, I would also like to personally thank you for the opportunity to work with you on this testing project and would enjoy the opportunity to work with you again on any additional future testing projects.

Sincerely,

Robert J. Lisy Jr.
Technical Manager

Table of Contents

1.0 Introduction

1.0 INTRODUCTION

1.1 Summary of Test Program

Powerspan Corp., headquartered in New Durham, New Hampshire, contracted Air Compliance Testing, Inc., of Cleveland, Ohio to conduct engineering performance (non-compliance) testing for their Electro-Catalytic Oxidation (ECO) Process installed at the FirstEnergy Berger Plant located in Shadyside, Ohio. The purpose of this emissions testing project was to validate the mercury concentrations reported by Powerspan Corp.'s Continuous Mercury Monitoring Systems. The testing was performed on May 8-10, 2002 for the Powerspan Corp.'s own internal purposes.

Sampling was performed at the ECO Process Inlet Duct and ECO Process Exhaust Duct to determine the flue gas concentrations of elemental, oxidized, particle-bound, and total mercury. Testing was conducted during baseline (non-spiked) flue gas conditions.

The test methods that were conducted during this test were abbreviated versions of EPA Reference Methods 1, 2, 3B, 4, and EPA Preliminary Test Method 3 (PRE3) (The Ontario Hydro Method).

1.2 Key Personnel

The key personnel who coordinated this test program (and their phone numbers) were:

Mathew Loomis, Project Coordinator, Powerspan, 603-859-2500

Philip Billick, Testing Director, Air Compliance Testing, Inc., 800-372-2471

Robert Lisy, Technical Manager, Air Compliance Testing, Inc., 800-372-2471

2.0 SUMMARY AND DISCUSSION OF TEST RESULTS

2.0 SUMMARY AND DISCUSSION OF TEST RESULTS

2.1 Objectives and Test Matrix

The purpose of this test was to determine the flue gas concentrations of elemental, oxidized, particle-bound, and total mercury at the ECO Process Inlet Duct and at the ECO Process Exhaust Duct during baseline (non-spiked) flue gas conditions in order to validate Powerspan Corp.'s Continuous Mercury Monitoring Systems. The testing was performed for Powerspan Corp.'s own internal purposes.

The specific test objectives for this were to:

Measure the flue gas concentrations of elemental, oxidized, particle-bound, and total mercury emissions at the ECO Process Inlet Duct and at the ECO Process Exhaust Duct during baseline (non-spiked) flue gas conditions.

Measure the dry standard and actual volumetric flow rate of the stack gas at the ECO Process Inlet Duct and at the ECO Process Exhaust Duct during baseline (non-spiked) flue gas conditions.

Table 2.1.1 presents the sampling and analytical matrix log for this test. Table 2.1.2 displays when the sampling ports were opened at the ECO Process Inlet Duct.

2.2 Field Test Changes and Problems

No field test changes or problems occurred during the performance of this test that would bias the accuracy of the results of this test.

2.3 Presentation of Results

A single sampling train was utilized during each run to determine the flue gas concentrations of elemental, oxidized, particle-bound, and total mercury at the ECO Process Inlet Duct and at the ECO Process Exhaust Duct during baseline (non-spiked) flue gas conditions. These trains measured the stack gas volumetric flow rate, dry molecular weight, moisture content, and flue gas concentrations of elemental, oxidized, particle-bound, and total mercury.

The flue gas concentrations of elemental, oxidized, particle-bound, and total mercury measured at the ECO Process Inlet Duct and at the ECO Process Exhaust Duct are displayed in Table 2.2. Also displayed in Table 2.2 are the mass emission rates of elemental, oxidized, particle-bound, and total mercury measured at the ECO Process Inlet Duct and at the ECO Process Exhaust Duct.

Mercury was determined by Cold Vapor Atomic Absorption Spectrophotometry (CVAA). The concentrations displayed in Table 2.2 utilize the actual mercury concentrations detected in the sample and blank fractions. In order to obtain positive values, the particle-bound and oxidized mercury fractions at the ECO Process Exhaust Duct were not blank-corrected.

			EPA TEST METHODS UTILIZED			
			M1/M2 (Flow)	**M3 (Dry Mol. Wt.)**	**M4 (%H_2O)**	**Ontarion Hydro (Mercury)**
Date	**Run No.**	**Sampling Location**	**Sampling Time / Duration (min)**	**Sampling Time / Duration (min)**	**Sampling Time / Duration (min)**	**Sampling Time / Duration (min)**
5/8/2002	1	ECO Inlet Duct	18:50 - 21:53 180	18:50 - 21:53 180	18:50 - 21:53 180	18:50 - 21:53 180
5/10/2002	2	ECO Inlet Duct	7:50 - 11:57 240	7:50 - 11:57 240	7:50 - 11:57 240	7:50 - 11:57 240
5/10/2002	3	ECO Inlet Duct	12:24 - 16:28 240	12:24 - 16:28 240	12:24 - 16:28 240	12:24 - 16:28 240
5/9/2002	1	ECO Exhaust Duct	8:25 - 11:30 180.4	8:25 - 11:30 180.4	8:25 - 11:30 180.4	8:25 - 11:30 180.4
5/9/2002	2	ECO Exhaust Duct	12:07 - 16:18 240	12:07 - 16:18 240	12:07 - 16:18 240	12:07 - 16:18 240
5/9/2002	3	ECO Exhaust Duct	16:58 - 21:02 240	16:58 - 21:02 240	16:58 - 21:02 240	16:58 - 21:02 240

All times are Eastern Standard Time.

Table 2.1.1 - Sampling and Analytical Matrix

Date	Run No.	Sampling Location	Initial Entry Time	First Port Change Time	Second Port Change Time	Final Removal Time
5/8/2002	1	ECO Inlet Duct	18:49	19:56	20:55	21:55
5/10/2002	2	ECO Inlet Duct	7:49	9:11	10:33	11:57
5/10/2002	3	ECO Inlet Duct	12:23	13:43	15:06	16:28

All times are Eastern Standard Time.

Table 2.1.2 - Port Change Matrix

	ECO Inlet Duct				ECO Exhaust Duct			
	Run 1	Run 2	Run 3	Average	Run 1	Run 2	Run 3	Average
Flue Gas Concentration of Particle-Bound Mercury (ug/dscm)	0.73	0.79	0.35	0.62	0.0062	0.021	0.021	0.016
Flue Gas Concentration of Oxidized Mercury (ug/dscm)	5.28	5.699	6.46	5.81	0.018	0.016	0.031	0.022
Flue Gas Concentration of Elemental Mercury (ug/dscm)	0.15	0.036	0.298	0.16	0.58	0.58	1.09	0.75
Flue Gas Concentration of Total Mercury (ug/dscm)	6.16	6.52	7.104	6.596	0.604	0.61	1.15	0.79
Mass Emission Rate of Particle-Bound Mercury (lb/hr)	2.62E-06	3.11E-06	1.14E-06	2.29E-06	2.36E-08	7.46E-08	7.78E-08	5.87E-08
Mass Emission Rate of Oxidized Mercury (lb/hr)	1.91E-05	2.26E-05	2.10E-05	2.09E-05	7.02E-08	5.61E-08	1.15E-07	8.05E-08
Mass Emission Rate of Elemental Mercury (lb/hr)	5.57E-07	1.44E-07	9.72E-07	5.58E-07	2.21E-06	2.05E-06	4.12E-06	2.79E-06
Mass Emission Rate of Total Mercury (lb/hr)	2.22E-05	2.59E-05	2.32E-05	2.38E-05	2.30E-06	2.18E-06	4.32E-06	2.93E-06
Flue Gas Average Flow Rate (acfm)	1,529	1,593	1,312	1,478	1,463	1,373	1,465	1,434
Flue Gas Average Flow Rate (dscfm)	963	1,059	870	964	1,017	951	1,006	991
Flue Gas Average Velocity (fpm)	382	398	328	370	366	343	366	358
Flue Gas Average Static Pressure (in-H_2O)	-16.4	-14.3	-16.1	-15.6	-13.0	-13.5	-14.1	-13.5
Flue Gas Average Temperature (°F)	255	241	243	246	154	153	159	155
Flue Gas Percent by Volume Moisture (%H_2O)	8.95	7.31	7.00	7.75	14.44	14.62	14.33	14.46
Measured Stack Inner Dimensions (in)*	24.0 x 24.0	24.0 x 24.0	24.0 x 24.0	24.0 x 24.0	24.0 x 24.0	24.0 x 24.0	24.0 x 24.0	24.0 x 24.0
Percent by Volume Carbon Dioxide in Flue Gas (Dry Basis) (%CO_2)	10.77	10.27	10.50	10.51	10.00	8.70	9.17	9.29
Percent by Volume Oxygen in Flue Gas (Dry Basis) (%O_2)	8.10	8.57	8.50	8.39	9.50	10.00	9.83	9.78
Percent by Volume Carbon Monoxide in Flue Gas (Dry Basis) (%CO)	0.03	0.03	0.00	0.02	0.07	0.10	0.00	0.06
Percent by Volume Nitrogen in Flue Gas (Dry Basis) (%N_2)	81.10	81.13	81.00	81.08	80.43	81.20	81.00	80.88

* The ECO Inlet Duct and Exhaust Stack were both rectangular in shape.

Table 2.2 - Emission Results

3.0 PLANT AND SAMPLING LOCATION DESCRIPTIONS

3.0 PLANT AND SAMPLING LOCATION DESCRIPTIONS

3.1 Process Description and Operation

See Powerspan Corp. personnel for a description of the ECO process.

3.2 Control Equipment Description

Mercury emissions were controlled by a Electro-Catalytic Oxidation (ECO) system.

3.3 Flue Gas Sampling Locations

3.3.1 ECO Process Inlet Duct

The ECO Inlet Duct measured 24-inches in depth by 24-inches in width, was oriented horizontally, and was accessed from the floor. Three (3) 4.0-inch sampling ports were located equidistant from one another at a point which met EPA Method 1, Section 11.1.1 criteria. The stack was traversed for stack gas volumetric flow rate, dry gas molecular weight, moisture content, and concentrations of elemental, oxidized, particle-bound, and total mercury.

3.3.2 ECO Exhaust Duct

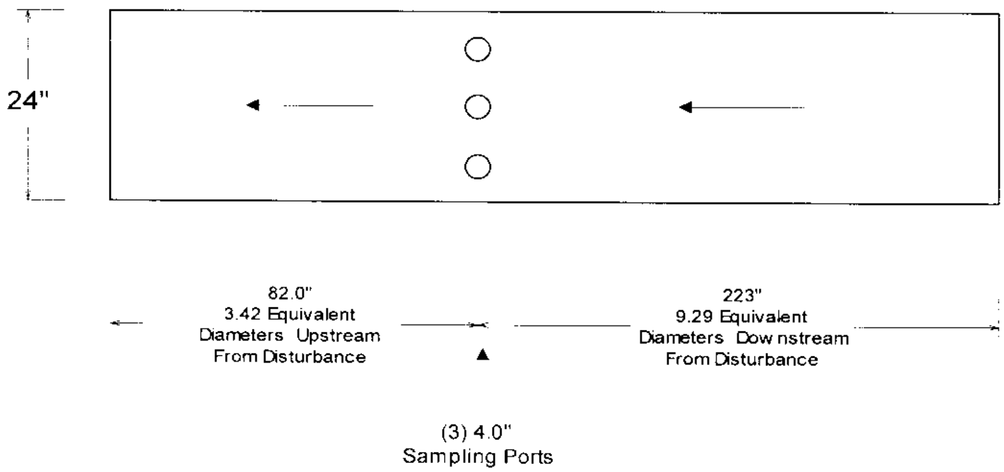
The ECO Exhuast Duct measured 24-inches in depth by 24-inches in width, was oriented horizontally, and was accessed from the floor. Three (3) 4.0-inch sampling ports were located equidistant from one another at a point which met EPA Method 1, Section 11.1.1 criteria. The stack was traversed for stack gas volumetric flow rate, dry gas molecular weight, moisture content, and concentrations of elemental, oxidized, particle-bound, and total mercury.

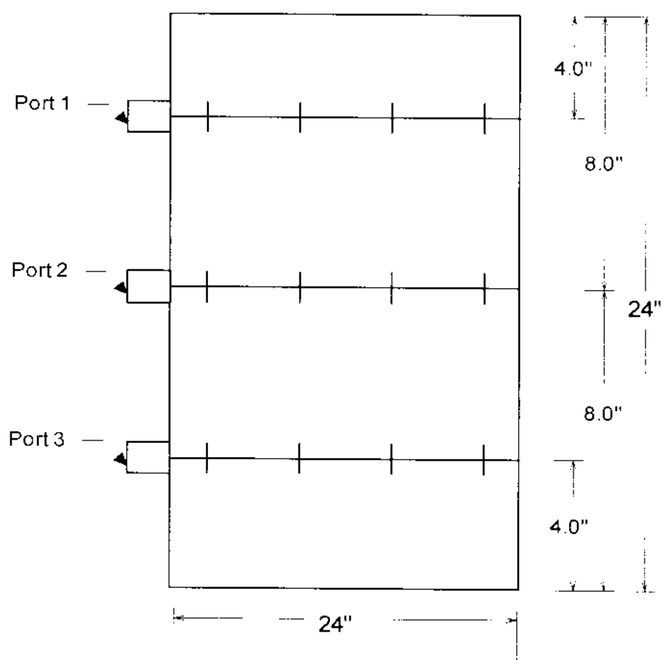
Figures 3.2 and 3.3 schematically illustrate the traverse point and sample port locations utilized.

3.4 Process Sampling Location

The EPA Reference Test Methods performed did not specifically require that process samples were to be taken during the performance of this testing event. It is in the best knowledge of Air Compliance Testing that no process samples were obtained and therefore no process sampling location was identified in this report.

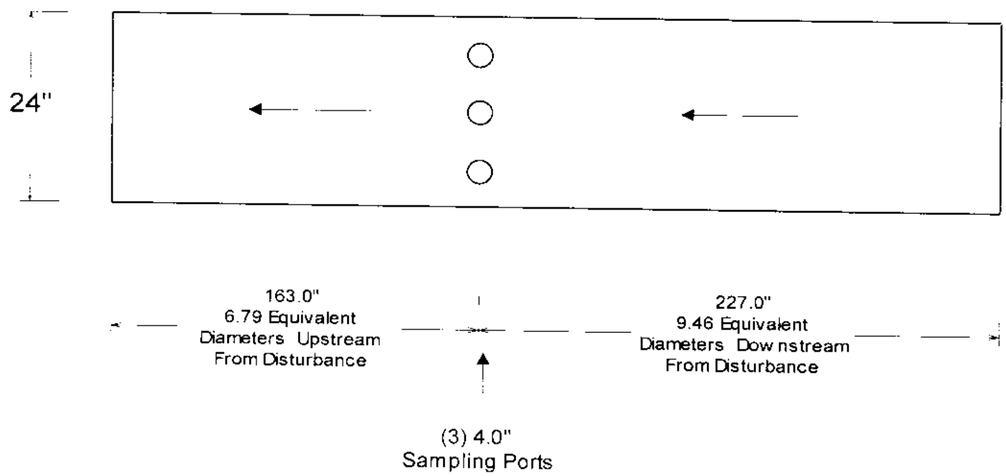
See Powerspan Corp. personnel for any process sampling locations which may have been utilized unknowingly to Air Compliance Testing, Inc. during this testing event.

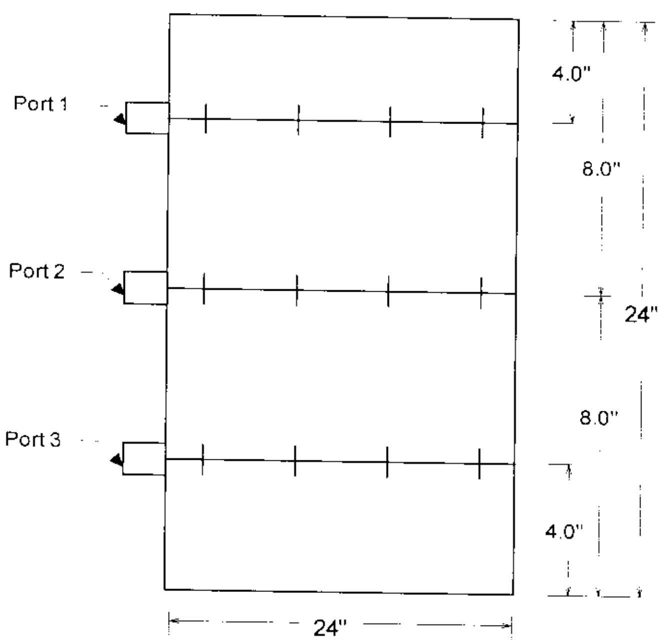




Point	% of Duct Depth	Distance From Inside Wall (in.)
1	12.5	3.0
2	37.5	9.0
3	62.5	15.0
4	87.5	21.0

Figure 3.1 - ECO Inlet Duct Traverse Point Location Drawing





Point	% of Duct Depth	Distance From Inside Wall (in.)
1	12.5	3.0
2	37.5	9.0
3	62.5	15.0
4	87.5	21.0

Figure 3.2 - ECO Exhaust Duct Traverse Point Location Drawing

4.0 SAMPLING AND ANALYTICAL PROCEDURES

4.0 SAMPLING AND ANALYTICAL PROCEDURES

4.1 Test Methods

4.1.1 EPA Method 1: Sample and Velocity Traverses for Stationary Source
Principle: Principle: To aid in the representative measurement of pollutant emissions and/or total volumetric flow rate from a stationary source, a measurement site where the effluent stream is flowing in a known direction is selected, and the cross-section of the stack is divided into a number of equal areas. A traverse point is then located within each of these equal areas. This method was utilized in its entirety as per the procedures outlined in 40 CFR Part 60, Appendix A.

4.1.2 EPA Method 2: Determination of Stack Gas Velocity and Volumetric Flow Rate (type S Pitot Tube)
Principle: The average gas velocity in a stack is determined from the gas density and from measurement of the average velocity head with a Type S (Stausscheibe or reverse type) pitot tube. This method was utilized in its entirety as per the procedures outlined in 40 CFR Part 60, Appendix A.

4.1.3 EPA Method 3B: Gas Analysis for the Determination of Emission Rate Correction Factor or Excess Air
Principle: A gas sample is extracted from a stack by one of the following methods: (1) single-point, grab sampling; (2) single-point, integrated sampling; or (3) multi-point, integrated sampling. The gas sample is analyzed for percent CO_2, percent O_2, and if necessary, for percent CO. An Orsat analyzer must be used for excess air or emission rate correction factor determination. This method was utilized in its entirety as per the procedures outlined in 40 CFR Part 60, Appendix A.

4.1.4 EPA Method 4: Determination of Moisture Content in Stack Gases
Principle: A gas sample is extracted at a constant rate from the source; moisture is removed from the sample stream and determined either volumetrically or gravimetrically. This method was utilized in its entirety as per the procedures outlined in 40 CFR Part 60, Appendix A.

4.1.5 Ontario Hydro Method: Standard Test Method for Elemental, Oxidized, Particle-Bound, and Total Mercury in Flue Gas Generated from Coal-Fired Stationary Sources
Principle: A sample is withdrawn from the flue gas stream isokinetically through a probe/filter system, maintained at 120°C or the flue gas temperature, whichever is greater, followed by a series of impingers in an ice bath. Particle-bound mercury is collected in the front half of the sampling train. Oxidized mercury (essentially mercuric chloride) is collected in impingers containing a chilled aqueous potassium chloride solution. Elemental mercury is collected in subsequent impingers (one impinger containing a chilled aqueous acidic solution of hydrogen peroxide and three impingers containing chilled aqueous acidic solutions of potassium permanganate). Samples are recovered, digested, and then analyzed for mercury using cold-vapor atomic absorption (CVAAS) of fluorescence spectroscopy (CVAFS). This method is applicable to Elemental, Oxidized, Particle-Bound, and Total Mercury concentrations ranging from approximately 0.5 to 100 μg/dscm.

The sampling train utilized during this testing project is depicted in Figure 4.1.

4.2 Procedures for Obtaining Process Data

See Powerspan personnel for process data collection procedures utilized during this testing event.

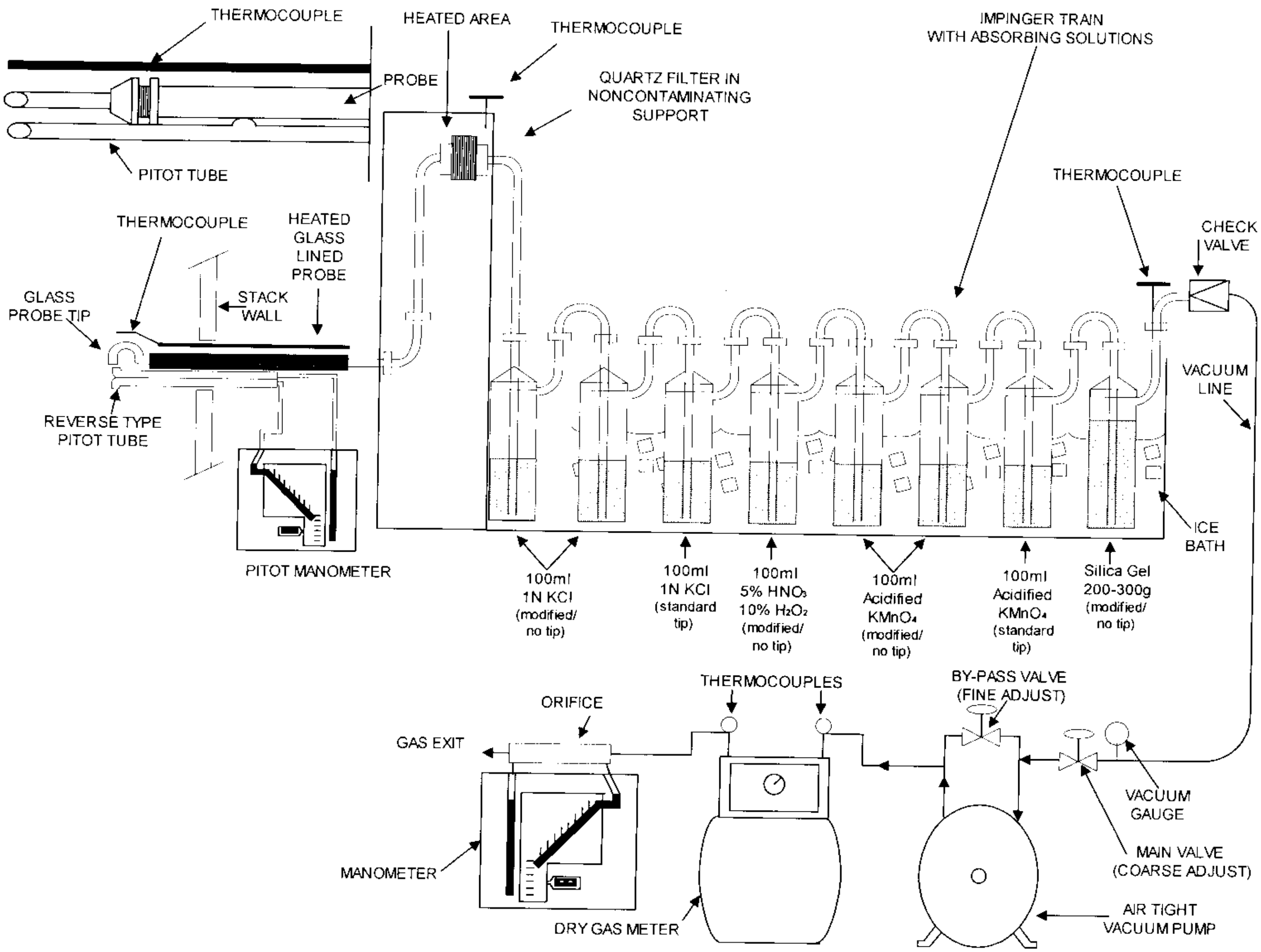


Figure 4.1 - Ontario Hydro Sampling Train Schematic

5.0 INTERNAL QA/QC ACTIVITIES

5.0 INTERNAL QA/QC ACTIVITIES

5.1 QA Audits

Tables 5.1 and 5.2 illustrate the QA audit activities that were performed during this test.

All meter boxes and sampling trains used during sampling performed within the requirements of their respective methods as is shown in Tables 5.1 and 5.2. All pre-test and post-test leak checks were well below the 0.02 cfm limit. Minimum metered volumes and percent isokinetics were also met where applicable.

Mercury was not detected above the minimum detection limit in any of the blanks. The spike recovery of 99.9% was within the normal range of 70 - 100%. Each sample was analyzed in duplicate. All of the replicates agreed within 10%.

5.2 QA/QC Problems

No QA/QC problems occurred during this test event.

ECO Inlet Duct									
Ontario Hydro Sampling Train	Leak Rate Observed (Pre/Post) (cfm)	Applicable Method Allowable Leak Rate (cfm)	Acceptable	Volume of Dry Gas Collected (dscf)	Recommended Volume of Dry Gas Collected (dscf)	Acceptable	Percent of Isokinetic Sampling Rate (%)	Applicable Method Allowable Isokinetic Sampling Rate	Acceptable
Run 1	0.002 / 0.001	<0.02	Yes	59.351	35.31 < x < 88.28	Yes	99.6	100 ± 10	Yes
Run 2	0.002 / 0.002	<0.02	Yes	90.159	35.31 < x < 88.28	Yes	103.3	100 ± 10	Yes
Run 3	0.000 / 0.000	<0.02	Yes	73.833	35.31 < x < 88.28	Yes	102.5	100 ± 10	Yes

ECO Exhaust Duct									
Ontario Hydro Sampling Train	Leak Rate Observed (Pre/Post) (cfm)	Applicable Method Allowable Leak Rate (cfm)	Acceptable	Volume of Dry Gas Collected (dscf)	Recommended Volume of Dry Gas Collected (dscf)	Acceptable	Percent of Isokinetic Sampling Rate (%)	Applicable Method Allowable Isokinetic Sampling Rate	Acceptable
Run 1	0.002 / 0.001	<0.02	Yes	62.713	35.31 < x < 88.28	Yes	99.0	100 ± 10	Yes
Run 2	0.002 / 0.001	<0.02	Yes	80.874	35.31 < x < 88.28	Yes	104.2	100 ± 10	Yes
Run 3	0.003 / 0.001	<0.02	Yes	83.756	35.31 < x < 88.28	Yes	100.6	100 ± 10	Yes

Table 5.1 - EPA Ontario Hydro Sample Train Audit Results Table

ECO Inlet Duct - Run 1				
Pre-Test Dry Gas Meter Calibration Factor (Y)	Average Post-Test Dry Gas Meter Calibration Check Value (Yqa)	Post Test Dry Gas Meter Gamma Difference From Pre-Test (%)	Applicable Method Allowable Difference (%)	Acceptable
1.0096	1.0202	1.05%	5.00%	Yes

ECO Inlet Duct - Runs 2 and 3				
Pre-Test Dry Gas Meter Calibration Factor (Y)	Average Post-Test Dry Gas Meter Calibration Check Value (Yqa)	Post Test Dry Gas Meter Gamma Difference From Pre-Test (%)	Applicable Method Allowable Difference (%)	Acceptable
1.0112	1.0108	-0.04%	5.00%	Yes

ECO Exhaust Duct				
Pre-Test Dry Gas Meter Calibration Factor (Y)	Average Post-Test Dry Gas Meter Calibration Check Value (Yqa)	Post Test Dry Gas Meter Gamma Difference From Pre-Test (%)	Applicable Method Allowable Difference (%)	Acceptable
1.0112	1.0425	3.10%	5.00%	Yes

Table 5.2 - Ontario Hydro Dry Gas Meter Audit Results Table

6.0 APPENDIX

Appendix attached.

APPENDIX

to

Engineering Performance Stack Emission Test Report

Determination of Elemental, Oxidized, Particle-Bound, and Total Mercury

Electro-Catalyitc Oxidation Process

EPA Methods 1, 2, 3B, 4, and Preliminary Test Method PRE3 (Ontario Hydro)

<u>**Powerspan Corp.**</u>
Shadyside, Ohio

Date Conducted: May 8-10, 2002
Job Number: 020301

Prepared by:

Air Compliance Testing, Inc.

PO Box 41156
Cleveland OH 44141-0156
Phone: (800) EPA-AIR1 (372-2471)

Report Date: June 10, 2002

TEST DATA

	Run 1	Run 2	Run 3	Average
Number of Test Runs	3			
Traverse Points	48			
Stack Cross-Sectional Width (**rectangular**) (W) (in)	24.0	24.0	24.0	24.0
Stack Cross-Sectional Depth (**rectangular**) (D) (in)	24.0	24.0	24.0	24.0
Pitot Tube Coefficient (Cp)	0.84	0.84	0.84	0.84
Barometric Pressure (Pbar) (in Hg)	29.25	29.52	29.58	29.45
Initial Dry Gas Meter Reading (ft3)	197.532	284.919	375.778	
Final Dry Gas Meter Reading (ft3)	258.750	375.430	450.808	
Dry Gas Meter Calibration Factor (Gamma)	1.0096	1.0112	1.0112	
Dry Gas Meter Calibration Coefficient (Delta H@)	1.744	1.8407	1.8407	1.8085
Total Sampling Run Time (Theta) (min)	180	240	240	220
Volume of Water Vapor Condensed in the Impingers (ml)	109.9	131.2	101.5	114.2
Weight of Water Vapor Collected in Silica Gel (grams)	14.0	19.9	16.6	16.8
Air Percent by Volume Carbon Dioxide in Stack Gas (Dry Basis) (%CO2)	10.77	10.27	10.50	10.51
Air Percent by Volume Oxygen in Stack Gas (Dry Basis) (%O2)	8.10	8.57	8.50	8.39
Air Percent by Volume Carbon Monoxide in Stack Gas (Dry Basis) (%CO)	0.03	0.03	0.00	0.02
Air Percent by Volume Nitrogen in Stack Gas (Dry Basis) (%N2)	81.10	81.13	81.00	81.08
Test Run Start Time (hrmin)	18:50	7:50	12:24	
Test Run Stop Time (hrmin)	21:53	11:57	16:28	

DETAILED RESULTS

Stack Gas Conditions

	Run 1	Run 2	Run 3	Average
Stack Cross-Sectional Area (A) (ft2)	4.0000	4.0000	4.0000	4.0000
Dry Molecular Weight of Stack Gas (Md) (lb/lb-mole)	30.047	29.986	30.020	30.018
Wet Molecular Weight of Stack Gas (Ms) (lb/lb-mole)	28.97	29.11	29.18	29.09
Average Absolute Stack Gas Pressure (Ps) (in Hg)	28.04	28.47	28.39	28.30
Average Stack Gas Static Pressure (ps) (in H2O)	-16.40	-14.27	-16.13	-15.60
Average Stack Gas Temperature (ts) (°F)	255.22	240.75	242.50	246.16
Average Stack Gas Temperature (Ts) (°R)	715.22	700.75	702.50	706.16
Average Stack Gas Velocity (Vs) (ft/sec)	6.37	6.64	5.47	6.16
Average Stack Gas Velocity (Vs) (ft/min)	382	398	328	370
Wet Volumetric Stack Gas Flow at Actual Conditions (Qaw) (acfm)	1,529	1,593	1,312	1,478
Wet Volumetric Stack Gas Flow at Standard Conditions (scfm)	1,058	1,142	936	1,045
Dry Volumetric Stack Gas Flow at Standard Conditions (Qstd) (dscfm)	963	1,059	870	964
Percent by Volume Moisture as measured in Stack Gas (%H2O)	8.95	7.31	7.00	7.75

Test Results

	Run 1	Run 2	Run 3	Average
Volume of Dry Gas Sampled at Standard Conditions (Vmstd) (dscf)	59.351	90.159	73.833	74.447
Dry Mole Fraction of Flue Gas (Mfd) (1-bw/100)	0.911	0.927	0.930	0.922
Average Velocity Pressure (Delta P) (in H2O)	0.0091	0.0103	0.0073	0.0089
Average Square Root of Delta P	0.09456	0.10053	0.08265	0.09258
Average Pressure Differential of Orifice Meter (Delta H) (in H2O)	0.3711	0.4742	0.3356	0.3936
Average DGM Temperature (tm) (°F)	78.028	69.458	76.854	74.780
Average Dry Gas Meter Temperature (Tm) (°R)	538.028	529.458	536.854	534.780
Volume of Metered Gas Sample (Vm) (dry) (acf)	61.218	90.511	75.030	75.586
Post-Test Calibration (Yqa)	1.0202	1.0005	1.0211	1.0139
Post-Test/Pre-Test Calibration Factor Difference (%)	-1.05	1.06	-0.97	-0.32

TEST DATA

	Run 1	Run 2	Run 3	Average
Probe Nozzle Diameter (in)	0.502	0.502	0.503	

DETAILED RESULTS

Test Results

Calculation Values

	Run 1	Run 2	Run 3	Average
Percent Isokinetic of Sampling Rate (% I)	99.6	103.3	102.5	
Probe Nozzle Cross-Sectional Area (ft2)	1.37E-03	1.37E-03	1.38E-03	1.38E-03

Emission Results

	Run 1	Run 2	Run 3	Average
Mass Emission Rate of Particle Bound Mercury (lb/hr)	2.62E-06	3.11E-06	1.14E-06	2.29E-06
Mass Emission Rate of Oxidized Mercury (lb/hr)	1.91E-05	2.26E-05	2.10E-05	2.09E-05
Mass Emission Rate of Elemental Mercury (lb/hr)	5.57E-07	1.44E-07	9.72E-07	5.58E-07
Mass Emission Rate of Total Mercury (lb/hr)	2.22E-05	2.59E-05	2.32E-05	2.38E-05

MERCURY CONCENTRATION CALC.

Lab Analysis Data for Analytical Fraction 1 (Filter)

	Run 1	Run 2	Run 3	Average
C (solution concentration of Hg in sample) (ug Hg/L)	1.73	2.65	0.87	1.75
Vml (volume of impinger plus rinses) (ml)	100	100	100	100
FV (volume of sample after digestion) (ml)	100	100	100	100
DV (volume of sample aliquot submitted to digestion) (ml)	20	20	20	20
Total Amount of Hg Collected on Filter (ug)	0.865	1.325	0.435	0.875
Blank Vml (volume of reagent blank) (ml)	100	100	100	100
Blank C (solution concentration of Hg in blank) (ug Hg/L)	0.07	0.07	0.07	0.07
Blank FV (volume of blank sample after digestion) (ml)	100	100	100	100
Blank DV (volume of blank sample aliquot submitted to digestion) (ml)	20	20	20	20
Total Amount of Hg Collected in Blank(ug)	0.035	0.035	0.035	0.035

Lab Analysis Data for Analytical Fraction 2 (Front-Half Rinse)

	Run 1	Run 2	Run 3	Average
C (solution concentration of Hg in sample) (ug Hg/L)	0.67	1.21	0.4	0.76
Vml (volume of impinger plus rinses) (ml)	120	120	170	137
FV (volume of sample after digestion) (ml)	100	100	100	100
DV (volume of sample aliquot submitted to digestion) (ml)	20	20	20	20
Total Amount of Hg Collected (ug)	0.402	0.726	0.340	0.489
Blank Vml (Volume of reagent blank) (Liters)	110	110	110	110
Blank C (solution concentration of Hg in blank) (ug Hg/L)	0.02	0.02	0.02	0.02
Blank FV (volume of blank sample after digestion) (ml)	100	100	100	100
Blank DV (volume of blank sample aliquot submitted to digestion) (ml)	20	20	20	20
Total Amount of Hg Collected in Blank(ug)	0.011	0.011	0.011	0.011

Lab Analysis Data for Analytical Fraction 3 (KCl Impingers)

	Run 1	Run 2	Run 3	Average
C (solution concentration of Hg in sample) (ug Hg/L)	3.23	5.16	5.02	4.47
Vml (volume of impinger plus rinses) (ml)	553	566	540	553
FV (volume of sample after digestion) (ml)	100	100	100	100
DV (volume of sample aliquot submitted to digestion) (ml)	20	20	20	20
Total Amount of Hg Collected (ug)	8.931	14.603	13.554	12.363
Blank Vml (Volume of reagent blank) (Liters)	540	540	540	540
Blank C (solution concentration of Hg in blank) (ug Hg/L)	0.02	0.02	0.02	0.02
Blank FV (volume of blank sample after digestion) (ml)	100	100	100	100
Blank DV (volume of blank sample aliquot submitted to digestion) (ml)	20	20	20	20
Total Amount of Hg Collected in Blank(ug)	0.054	0.054	0.054	0.054

Lab Analysis Data for Analytical Fraction 4 (H2O2 Impingers)

	Run 1	Run 2	Run 3	Average
C (solution concentration of Hg in sample) (ug Hg/L)	**0.07**	**0.01**	**0.01**	0.03
Vml (volume of impinger plus rinses) (ml)	**207**	**212**	**209**	209
FV (volume of sample after digestion) (ml)	**100**	**100**	**100**	100
DV (volume of sample aliquot submitted to digestion) (ml)	**10**	**10**	**10**	10
Total Amount of Hg Collected (ug)	0.145	0.021	0.021	0.062
Blank Vml (Volume of reagent blank) (Liters)	**202**	**202**	**202**	202
Blank C (solution concentration of Hg in blank) (ug Hg/L)	**0.04**	**0.04**	**0.04**	0.04
Blank FV (volume of blank sample after digestion) (ml)	**100**	**100**	**100**	100
Blank DV (volume of blank sample aliquot submitted to digestion) (ml)	**5**	**5**	**5**	5
Total Amount of Hg Collected in Blank(ug)	0.162	0.162	0.162	0.162

Lab Analysis Data for Analytical Fraction 5 (KMnO4 Impingers)

	Run 1	Run 2	Run 3	Average
C (solution concentration of Hg in sample) (ug Hg/L)	**0.23**	**0.17**	**0.36**	0.25
Vml (volume of impinger plus rinses) (ml)	**460**	**464**	**463**	462
FV (volume of sample after digestion) (ml)	**100**	**100**	**100**	100
DV (volume of sample aliquot submitted to digestion) (ml)	**20**	**20**	**20**	20
Total Amount of Hg Collected (ug)	0.529	0.394	0.833	0.586
Blank Vml (Volume of reagent blank) (Liters)	**460**	**460**	**460**	460
Blank C (solution concentration of Hg in blank) (ug Hg/L)	**0.11**	**0.07**	**0.03**	0.07
Blank FV (volume of blank sample after digestion) (ml)	**100**	**100**	**100**	100
Blank DV (volume of blank sample aliquot submitted to digestion) (ml)	**20**	**20**	**20**	20
Total Amount of Hg Collected in Blank(ug)	0.253	0.161	0.069	0.161

Particle Bound Mercury Calculations

	Run 1	Run 2	Run 3	Average
Mass of Particulate Hg Collected in the Sampling Train (µg)	1.221	2.005	0.729	1.318
Stack Gas Concentration of Particulate Hg (mg/dscm)	0.001	0.001	0.000	0.001
Stack Gas Concentration of Particulate Hg (lb/dscf)	4.535E-11	4.903E-11	2.177E-11	3.872E-11

Oxidized Mercury Calculations

	Run 1	Run 2	Run 3	Average
Mass of Oxidized Hg Collected in the Sampling Train (µg)	8.877	14.549	13.500	12.309
Stack Gas Concentration of Oxidized Hg (mg/dscm)	0.005	0.006	0.006	0.006
Stack Gas Concentration of Oxidized Hg (lb/dscf)	3.297E-10	3.558E-10	4.031E-10	3.629E-10

Elemental Mercury Calculations

	Run 1	Run 2	Run 3	Average
Mass of Elemental Hg Collected in the Sampling Train (µg)	0.259	0.093	0.624	0.325
Stack Gas Concentration of Elemental Hg (mg/dscm)	0.000	0.000	0.000	0.000
Stack Gas Concentration of Elemental Hg (lb/dscf)	9.632E-12	2.274E-12	1.862E-11	1.018E-11

Total Mercury Calculations

	Run 1	Run 2	Run 3	Average
Mass of Total Hg Collected in the Sampling Train (µg)	10.357	16.647	14.853	13.952
Stack Gas Concentration of Total Hg (mg/dscm)	0.0062	0.0065	0.0071	0.0066
Stack Gas Concentration of Total Hg (lb/dscf)	3.847E-10	4.071E-10	4.435E-10	4.118E-10
Volume of Gas Sample as Measured by the Dry Gas Meter Corrected to Dry Standard Conditions (dscm)	1.681	2.553	2.091	2.108

MEASURED DATA FROM TEST RUNS

Point Count	Run #	Run Time (min)	Pitot Delta P (in H2O)	Square Root of Delta P	Orifice Delta H (in H2O)	DGM Temp IN (°F)	DGM Temp OUT (°F)	Average DGM Temp (°F)	Stack Pressure (in H2O)	Stack Temp (°F)
1	1	**0**	**0.010**	0.100	**0.42**	**75**	**72**	73.50	**-16.4**	**260**
2	1	**5**	**0.010**	0.100	**0.42**	**77**	**73**	75.00		**274**
3	1	**10**	**0.012**	0.110	**0.43**	**78**	**74**	76.00		**275**
4	1	**15**	**0.012**	0.110	**0.43**	**79**	**74**	76.50		**276**
5	1	**20**	**0.012**	0.110	**0.43**	**80**	**74**	77.00		**276**
6	1	**25**	**0.012**	0.110	**0.43**	**81**	**75**	78.00		**276**
7	1	**30**	**0.012**	0.110	**0.43**	**81**	**75**	78.00		**274**
8	1	**35**	**0.012**	0.110	**0.43**	**81**	**75**	78.00		**274**
9	1	**40**	**0.010**	0.100	**0.42**	**82**	**76**	79.00		**274**
10	1	**45**	**0.010**	0.100	**0.42**	**82**	**76**	79.00		**264**
11	1	**50**	**0.005**	0.071	**0.21**	**81**	**76**	78.50		**253**
12	1	**55**	**0.008**	0.089	**0.33**	**80**	**76**	78.00		**241**
13	1	**60**	**0.010**	0.100	**0.42**	**81**	**76**	78.50		**241**
14	1	**65**	**0.005**	0.071	**0.21**	**81**	**76**	78.50		**140**
15	1	**70**	**0.005**	0.071	**0.21**	**81**	**76**	78.50		**145**
16	1	**75**	**0.008**	0.089	**0.33**	**81**	**76**	78.50		**147**
17	1	**80**	**0.017**	0.130	**0.71**	**82**	**76**	79.00		**268**
18	1	**85**	**0.010**	0.100	**0.42**	**83**	**76**	79.50		**270**
19	1	**90**	**0.010**	0.100	**0.42**	**82**	**76**	79.00		**272**
20	1	**95**	**0.010**	0.100	**0.42**	**82**	**76**	79.00		**273**
21	1	**100**	**0.010**	0.100	**0.42**	**82**	**76**	79.00		**273**
22	1	**105**	**0.009**	0.095	**0.38**	**82**	**76**	79.00		**273**
23	1	**110**	**0.010**	0.100	**0.42**	**82**	**76**	79.00		**273**
24	1	**115**	**0.010**	0.100	**0.42**	**82**	**76**	79.00		**273**
25	1	**120**	**0.010**	0.100	**0.42**	**80**	**76**	78.00		**257**
26	1	**125**	**0.010**	0.100	**0.42**	**81**	**76**	78.50		**262**
27	1	**130**	**0.010**	0.100	**0.42**	**81**	**76**	78.50		**266**
28	1	**135**	**0.006**	0.077	**0.25**	**81**	**76**	78.50		**266**
29	1	**140**	**0.007**	0.084	**0.29**	**80**	**75**	77.50		**266**
30	1	**145**	**0.008**	0.089	**0.34**	**81**	**75**	78.00		**267**
31	1	**150**	**0.009**	0.095	**0.38**	**81**	**75**	78.00		**258**
32	1	**155**	**0.008**	0.089	**0.34**	**81**	**76**	78.50		**268**
33	1	**160**	**0.007**	0.084	**0.29**	**81**	**75**	78.00		**268**
34	1	**165**	**0.005**	0.071	**0.21**	**80**	**75**	77.50		**252**
35	1	**170**	**0.005**	0.071	**0.21**	**80**	**75**	77.50		**247**
36	1	**175**	**0.005**	0.071	**0.21**	**80**	**75**	77.50		**246**
37	1									
38	1									
39	1									
40	1									
41	1									
42	1									
43	1									
44	1									
45	1									
46	1									
47	1									
48	1									

Point Count	Run #	Run Time (min)	Pitot Delta P (in H2O)	Square Root of Delta P	Orifice Delta H (in H2O)	DGM Temp IN (°F)	DGM Temp OUT (°F)	Average DGM Temp (°F)	Stack Pressure (in H2O)	Stack Temp (°F)
49	2	**0**	**0.011**	0.105	**0.55**		**58**	58.00	**-15.2**	**255**
50	2	**5**	**0.013**	0.114	**0.60**		**58**	58.00		**264**
51	2	**10**	**0.013**	0.114	**0.60**		**58**	58.00		**264**
52	2	**15**	**0.013**	0.114	**0.60**		**60**	60.00		**264**
53	2	**20**	**0.014**	0.118	**0.65**		**61**	61.00		**264**
54	2	**25**	**0.014**	0.118	**0.65**		**62**	62.00		**263**
55	2	**30**	**0.014**	0.118	**0.65**		**63**	63.00		**263**
56	2	**35**	**0.014**	0.118	**0.65**		**64**	64.00		**263**
57	2	**40**	**0.011**	0.105	**0.55**		**64**	64.00		**262**
58	2	**45**	**0.010**	0.100	**0.46**		**65**	65.00		**261**
59	2	**50**	**0.010**	0.100	**0.46**		**66**	66.00		**260**
60	2	**55**	**0.010**	0.100	**0.46**		**67**	67.00		**260**
61	2	**60**	**0.010**	0.100	**0.46**		**67**	67.00		**218**
62	2	**65**	**0.010**	0.100	**0.46**		**68**	68.00		**167**
63	2	**70**	**0.010**	0.100	**0.46**		**69**	69.00		**160**
64	2	**75**	**0.010**	0.100	**0.46**		**69**	69.00		**160**
65	2	**80**	**0.010**	0.100	**0.46**		**70**	70.00		**126**
66	2	**85**	**0.010**	0.100	**0.46**		**70**	70.00		**204**
67	2	**90**	**0.010**	0.100	**0.46**		**70**	70.00		**215**
68	2	**95**	**0.010**	0.100	**0.46**		**71**	71.00		**213**
69	2	**100**	**0.015**	0.122	**0.70**		**71**	71.00		**240**
70	2	**105**	**0.016**	0.126	**0.74**		**72**	72.00		**259**
71	2	**110**	**0.015**	0.122	**0.70**		**72**	72.00		**255**
72	2	**115**	**0.010**	0.100	**0.46**		**72**	72.00		**259**
73	2	**120**	**0.010**	0.100	**0.46**		**73**	73.00		**260**
74	2	**125**	**0.010**	0.100	**0.46**		**73**	73.00		**263**
75	2	**130**	**0.010**	0.100	**0.46**		**73**	73.00		**263**
76	2	**135**	**0.010**	0.100	**0.46**		**73**	73.00		**263**
77	2	**140**	**0.010**	0.100	**0.46**		**73**	73.00		**263**
78	2	**145**	**0.010**	0.100	**0.46**		**73**	73.00		**263**
79	2	**150**	**0.011**	0.105	**0.50**		**73**	73.00		**263**
80	2	**155**	**0.010**	0.100	**0.46**		**73**	73.00		**263**
81	2	**160**	**0.010**	0.100	**0.46**		**73**	73.00		**236**
82	2	**165**	**0.010**	0.100	**0.46**		**73**	73.00		**257**
83	2	**170**	**0.010**	0.100	**0.46**		**73**	73.00		**258**
84	2	**175**	**0.010**	0.100	**0.46**		**73**	73.00		**259**
85	2	**180**	**0.010**	0.100	**0.46**		**72**	72.00		**257**
86	2	**185**	**0.010**	0.100	**0.46**		**72**	72.00	**-11.4**	**257**
87	2	**190**	**0.007**	0.084	**0.32**		**72**	72.00		**257**
88	2	**195**	**0.007**	0.084	**0.32**		**72**	72.00		**257**
89	2	**200**	**0.007**	0.084	**0.32**		**72**	72.00		**255**
90	2	**205**	**0.007**	0.084	**0.32**		**73**	73.00		**253**
91	2	**210**	**0.007**	0.084	**0.32**		**73**	73.00		**253**
92	2	**215**	**0.007**	0.084	**0.32**		**73**	73.00		**252**
93	2	**220**	**0.007**	0.084	**0.32**		**73**	73.00		**220**
94	2	**225**	**0.007**	0.084	**0.32**		**73**	73.00		**191**
95	2	**230**	**0.006**	0.077	**0.28**		**73**	73.00		**187**
96	2	**235**	**0.006**	0.077	**0.28**		**73**	73.00	**-16.2**	**187**

Point Count	Run #	Run Time (min)	Pitot Delta P (in H2O)	Square Root of Delta P	Orifice Delta H (in H2O)	DGM Temp IN (°F)	DGM Temp OUT (°F)	Average DGM Temp (°F)	Stack Pressure (in H2O)	Stack Temp (°F)
97	3	**0**	**0.014**	0.118	**0.65**		**72**	72.00		**236**
98	3	**5**	**0.014**	0.118	**0.65**		**73**	73.00		**260**
99	3	**10**	**0.012**	0.110	**0.56**		**73**	73.00		**262**
100	3	**15**	**0.012**	0.110	**0.56**		**73**	73.00		**263**
101	3	**20**	**0.012**	0.110	**0.56**		**73**	73.00		**263**
102	3	**25**	**0.013**	0.114	**0.60**		**74**	74.00		**263**
103	3	**30**	**0.013**	0.114	**0.60**		**74**	74.00		**263**
104	3	**35**	**0.012**	0.110	**0.56**		**74**	74.00		**263**
105	3	**40**	**0.012**	0.110	**0.56**		**74**	74.00		**261**
106	3	**45**	**0.011**	0.105	**0.51**		**74**	74.00	**-16.6**	**260**
107	3	**50**	**0.011**	0.105	**0.51**		**74**	74.00		**260**
108	3	**55**	**0.011**	0.105	**0.51**		**75**	75.00		**261**
109	3	**60**	**0.010**	0.100	**0.46**		**75**	75.00		**215**
110	3	**65**	**0.010**	0.100	**0.46**		**75**	75.00		**184**
111	3	**70**	**0.010**	0.100	**0.46**		**75**	75.00		**180**
112	3	**75**	**0.009**	0.095	**0.42**		**75**	75.00		**164**
113	3	**80**	**0.007**	0.084	**0.32**		**75**	75.00	**-16.2**	**115**
114	3	**85**	**0.005**	0.071	**0.23**		**75**	75.00		**188**
115	3	**90**	**0.006**	0.077	**0.26**		**76**	76.00		**223**
116	3	**95**	**0.006**	0.077	**0.26**		**76**	76.00		**228**
117	3	**100**	**0.006**	0.077	**0.26**		**76**	76.00		**240**
118	3	**105**	**0.005**	0.071	**0.23**		**76**	76.00		**259**
119	3	**110**	**0.006**	0.077	**0.26**		**76**	76.00		**260**
120	3	**115**	**0.006**	0.077	**0.26**		**76**	76.00		**260**
121	3	**120**	**0.006**	0.077	**0.28**		**76**	76.00		**260**
122	3	**125**	**0.006**	0.077	**0.28**		**77**	77.00		**262**
123	3	**130**	**0.007**	0.084	**0.32**		**77**	77.00		**261**
124	3	**135**	**0.007**	0.084	**0.32**		**77**	77.00		**261**
125	3	**140**	**0.006**	0.077	**0.28**		**77**	77.00		**261**
126	3	**145**	**0.007**	0.084	**0.32**		**78**	78.00		**261**
127	3	**150**	**0.008**	0.089	**0.37**		**78**	78.00		**262**
128	3	**155**	**0.007**	0.084	**0.32**		**78**	78.00		**261**
129	3	**160**	**0.004**	0.063	**0.19**		**79**	79.00		**217**
130	3	**165**	**0.004**	0.063	**0.19**		**79**	79.00		**250**
131	3	**170**	**0.004**	0.063	**0.19**		**79**	79.00		**255**
132	3	**175**	**0.004**	0.063	**0.19**		**79**	79.00		**255**
133	3	**180**	**0.004**	0.063	**0.19**		**80**	80.00		**255**
134	3	**185**	**0.004**	0.063	**0.19**		**80**	80.00		**253**
135	3	**190**	**0.004**	0.063	**0.19**		**80**	80.00	**-15.6**	**253**
136	3	**195**	**0.004**	0.063	**0.19**		**80**	80.00		**253**
137	3	**200**	**0.004**	0.063	**0.19**		**81**	81.00		**249**
138	3	**205**	**0.004**	0.063	**0.19**		**81**	81.00		**249**
139	3	**210**	**0.003**	0.055	**0.15**		**81**	81.00		**250**
140	3	**215**	**0.002**	0.045	**0.10**		**81**	81.00		**250**
141	3	**220**	**0.002**	0.045	**0.10**		**81**	81.00		**251**
142	3	**225**	**0.002**	0.045	**0.10**		**81**	81.00		**251**
143	3	**230**	**0.006**	0.077	**0.28**		**80**	80.00		**215**
144	3	**235**	**0.006**	0.077	**0.28**		**80**	80.00		**214**

EPA Methods 1, 2, 3, 4 and PRE 003
Nomenclature and Sample Calculations
ECO Inlet Duct - Run 3

Constants

$CO2F_{wt} := 44$ $O2F_{wt} := 32$ $CON2F_{wt} := 28$ $H2OF_{wt} := 18$ $in\_wg := 0.073529 \cdot in\_Hg$ $gr := \frac{lb}{7000}$

$mmBtu := 1 \cdot 10^6 \cdot BTU$ $CF_{wt} := 12.011$ $NO2F_{wt} := 46.005$ $COF_{wt} := 28.01$ $H2SO4F_{wt} := 98.0756$ $F := R$

$HClF_{wt} := 36.46$ $SO2F_{wt} := 64.0628$

Measured Stack Variables

$A := 4 \cdot ft^2$	stack cross-sectional area (ft^2)
$C_p := .84$	pitot tube coefficient (dimensionless)
$P_{bar} := 29.58 \cdot in\_Hg$	barometric pressure (in. Hg)
$\theta := 240 \cdot min$	net run time (minutes)
$\%CO_2 := 10.5$	percent CO_2 by volume (dry basis) (dimensionless)
$\%O_2 := 8.5$	percent O_2 by volume (dry basis) (dimensionless)
$\%CO := 0.0$	percent CO by volume (dry basis) (dimensionless)
$\%N_2 := 81.0$	percent N_2 by volume (dry basis) (dimensionless)
$P_g := -16.13 \cdot in\_wg$	flue gas static pressure (in. H_2O)
$P_{std} := 29.92 \cdot in\_Hg$	standard absolute pressure at 29.92 inches of Hg
$T_m := 536.854 \cdot R$	dry gas meter temperature (460 R + t_m °F) (Rankine)
$T_{savg} := 702.5 \cdot R$	average absolute flue gas temperature (460 R + t_{savg} °F) (Rankine)
$T_{std} := 528 \cdot R$	standard absolute temperature (460 R + t_{std} °F) (Rankine)
$\Delta H := .3356 \cdot in\_wg$	average pressure differential of orifice meter (in_wg)
$SQ\Delta P_{avg} := .08265^2 \cdot in\_wg$	square of average square root ΔP [(in_wg)]
$V_m := 75.03 \cdot ft^3$	volume of metered gas sample (dry actual cubic feet)
$\gamma := 1.0112$	gamma, dry gas meter calibration factor (dimensionless)
$NOZDIA := .503 \cdot in$	sampling nozzle diameter (in.)
$V_{lc} := 118.1 \cdot mL$	total volume of liquid collected in impingers and silica gel (1g = 1ml)

$mgquanHg := 0.014853 \cdot mg$ total Hg catch mass (mg)

Calculated Stack Variables

Volume of dry gas sampled at standard conditions, (dscf)

$$V_{mstd} := \gamma \cdot V_m \cdot \frac{P_{bar} + \Delta H}{P_{std}} \cdot \frac{T_{std}}{T_m}$$

$$V_{mstd} = 73.833\ ft^3$$

Volume of water vapor at standard conditions (68 °F, scf)

$$V_{wstd} := \frac{0.04707 \cdot ft^3}{mL} \cdot V_{lc}$$

$$V_{wstd} = 5.559\ ft^3$$

Percent moisture by volume as measured in flue gas

$$\%H2O := (100) \cdot \frac{V_{wstd}}{V_{wstd} + V_{mstd}}$$

$$\%H2O = 7$$

Absolute flue gas pressure (in. Hg)

$$P_s := P_{bar} + P_g$$

$$P_s = 28.39 \circ in\_Hg$$

Dry mole fraction of flue gas (dimensionless)

$$M_{fd} := 1 - \frac{\%H2O}{100}$$

$$M_{fd} = 0.93$$

Dry molecular weight of flue gas (lb/lb-mole)

$$M_d := \frac{\%CO_2}{100} \cdot CO2F_{wt} + \frac{\%O_2}{100} \cdot O2F_{wt} + \frac{100 - \%CO_2 - \%O_2}{100} \cdot CON2F_{wt}$$

$$M_d = 30.02$$

Wet molecular weight of flue gas (lb/lb-mole)

$$M_s := M_d \cdot M_{fd} + H2OF_{wt} \cdot \frac{\%H2O}{100}$$

$$M_s = 29.18$$

Average flue gas velocity (NB: ΔP_{avg} is square of average square root) (ft/sec)

$$v_s := 85.49 \cdot \frac{ft}{sec} \cdot \left(\frac{in\_Hg}{R \cdot in\_wg}\right)^{0.5} \cdot C_p \cdot \sqrt{SQ\Delta P_{avg}} \cdot \sqrt{\frac{T_{savg}}{P_s \cdot M_s}}$$

$$v_s = 5.47\ ft \cdot sec^{-1}$$

Wet volumetric flue gas flow rate at actual conditions (acfm)

$$Q_{aw} := v_s \cdot A$$

$$Q_{aw} = 1312 \circ \frac{ft^3}{min}$$

Dry volumetric flue gas flow rate at standard conditions (dscfm)

$$Q_{sd} := M_{fd} \cdot v_s \cdot A \cdot \frac{T_{std}}{T_{savg}} \cdot \frac{P_s}{P_{std}}$$

$$Q_{sd} = 870 \circ \frac{ft^3}{min}$$

Dry air flow rate at standard conditions (lb/hr)

$$Q_{lb} := \frac{Q_{sd} \cdot M_d \cdot lb}{385.3 \cdot ft^3}$$

$$Q_{lb} = 4.067 \cdot 10^3 \circ \frac{lb}{hr}$$

Isokinetic Calculations

Percent isokinetic of sampling rate (%)

$$\%I := \frac{P_{std}}{T_{std}} \cdot \frac{T_{savg}}{P_s} \cdot \left[\frac{V_{mstd}}{v_s \cdot M_{fd} \cdot \theta \cdot \pi \cdot \left(\frac{NOZDIA}{2} \right)^2} \right]$$

$$\%I = 102.5 \circ \%$$

Total Hg concentration (mg/dscm)

$$ConcHgmgcm := \frac{mgquanHg}{V_{mstd}}$$

$$ConcHgmgcm = 0.0071 \circ \frac{mg}{m^3}$$

Total Hg mass emission rate (lb/hr)

$$HgEMRlbhr := \frac{mgquanHg}{V_{mstd}} \cdot Q_{sd}$$

$$HgEMRlbhr = 2.32 \cdot 10^{-5} \circ \frac{lb}{hr}$$

TEST DATA

	Run 1	Run 2	Run 3	Average
Number of Test Runs	3			
Traverse Points	48			
Stack Cross-Sectional Width (**rectangular**) (W) (in)	**24.0**	**24.0**	**24.0**	24.0
Stack Cross-Sectional Depth (**rectangular**) (D) (in)	**24.0**	**24.0**	**24.0**	24.0
Pitot Tube Coefficient (Cp)	**0.84**	**0.84**	**0.84**	0.84
Barometric Pressure (Pbar) (in Hg)	**29.23**	**29.15**	**29.15**	29.18
Initial Dry Gas Meter Reading (ft3)	**45.677**	**110.981**	**196.699**	
Final Dry Gas Meter Reading (ft3)	**110.751**	**196.370**	**284.559**	
Dry Gas Meter Calibration Factor (Gamma)	**1.0112**	**1.0112**	**1.0112**	1.0112
Dry Gas Meter Calibration Coefficient (Delta H@)	**1.8407**	**1.8407**	**1.8407**	1.8407
Total Sampling Run Time (Theta) (min)	**180.7**	**240.42**	**240**	220.37
Volume of Water Vapor Condensed in the Impingers (ml)	**210.7**	**276.0**	**280.9**	255.9
Weight of Water Vapor Collected in Silica Gel (grams)	**14.1**	**18.1**	**16.7**	16.3
Air Percent by Volume Carbon Dioxide in Stack Gas (Dry Basis) (%CO2)	**10.00**	**8.70**	**9.17**	9.29
Air Percent by Volume Oxygen in Stack Gas (Dry Basis) (%O2)	**9.50**	**10.00**	**9.83**	9.78
Air Percent by Volume Carbon Monoxide in Stack Gas (Dry Basis) (%CO)	**0.07**	**0.10**	**0.00**	0.06
Air Percent by Volume Nitrogen in Stack Gas (Dry Basis) (%N2)	**80.43**	**81.20**	**81.00**	80.88
Test Run Start Time (hrmin)	**8:25**	**12:07**	**16:58**	
Test Run Stop Time (hrmin)	**11:30**	**16:18**	**21:02**	

DETAILED RESULTS

Stack Gas Conditions

	Run 1	Run 2	Run 3	Average
Stack Cross-Sectional Area (A) (ft2)	4.0000	4.0000	4.0000	4.0000
Dry Molecular Weight of Stack Gas (Md) (lb/lb-mole)	29.980	29.792	29.860	29.877
Wet Molecular Weight of Stack Gas (Ms) (lb/lb-mole)	28.25	28.07	28.16	28.16
Average Absolute Stack Gas Pressure (Ps) (in Hg)	28.27	28.16	28.11	28.18
Average Stack Gas Static Pressure (ps) (in H2O)	-13.00	-13.45	-14.10	-13.52
Average Stack Gas Temperature (ts) (°F)	154.42	152.73	158.96	155.37
Average Stack Gas Temperature (Ts) (°R)	614.42	612.73	618.96	615.37
Average Stack Gas Velocity (Vs) (ft/sec)	6.10	5.72	6.10	5.97
Average Stack Gas Velocity (Vs) (ft/min)	366	343	366	358
Wet Volumetric Stack Gas Flow at Actual Conditions (Qaw) (acfm)	1,463	1,373	1,465	1,434
Wet Volumetric Stack Gas Flow at Standard Conditions (scfm)	1,188	1,113	1,174	1,159
Dry Volumetric Stack Gas Flow at Standard Conditions (Qstd) (dscfm)	1,017	951	1,006	991
Percent by Volume Moisture as measured in Stack Gas (%H2O)	14.44	14.62	14.33	14.46

Test Results

	Run 1	Run 2	Run 3	Average
Volume of Dry Gas Sampled at Standard Conditions (Vmstd) (dscf)	62.713	80.874	83.756	75.781
Dry Mole Fraction of Flue Gas (Mfd) (1-bw/100)	0.856	0.854	0.857	0.855
Average Velocity Pressure (Delta P) (in H2O)	0.0097	0.0083	0.0094	0.0091
Average Square Root of Delta P	0.09680	0.09047	0.09612	0.09446
Average Pressure Differential of Orifice Meter (Delta H) (in H2O)	0.5064	0.4017	0.4431	0.4504
Average DGM Temperature (tm) (°F)	81.833	89.771	86.271	85.958
Average Dry Gas Meter Temperature (Tm) (°R)	541.833	549.771	546.271	545.958
Volume of Metered Gas Sample (Vm) (dry) (acf)	65.074	85.389	87.860	79.441
Post-Test Calibration (Yqa)	1.1009	1.0060	1.0207	1.0425
Post-Test/Pre-Test Calibration Factor Difference (%)	-8.87	0.51	-0.94	-3.10

TEST DATA

	Run 1	Run 2	Run 3	Average
Probe Nozzle Diameter (in)	0.503	0.499	0.503	

DETAILED RESULTS

Test Results

	Run 1	Run 2	Run 3	Average
Percent Isokinetic of Sampling Rate (% I)	99.0	104.2	100.6	

Calculation Values

	Run 1	Run 2	Run 3	Average
Probe Nozzle Cross-Sectional Area (ft2)	1.38E-03	1.36E-03	1.38E-03	1.37E-03

Emission Results

	Run 1	Run 2	Run 3	Average
Mass Emission Rate of Particle Bound Mercury (lb/hr)	2.36E-08	7.46E-08	7.78E-08	5.87E-08
Mass Emission Rate of Oxidized Mercury (lb/hr)	7.02E-08	5.61E-08	1.15E-07	8.05E-08
Mass Emission Rate of Elemental Mercury (lb/hr)	2.21E-06	2.05E-06	4.12E-06	2.79E-06
Mass Emission Rate of Total Mercury (lb/hr)	2.30E-06	2.18E-06	4.32E-06	2.93E-06

MERCURY CONCENTRATION CALC.

Lab Analysis Data for Analytical Fraction 1 (Filter)

	Run 1	Run 2	Run 3	Average
C (solution concentration of Hg in sample) (ug Hg/L)	0	0.06	0.05	0.04
Vml (volume of impinger plus rinses) (ml)	100	100	100	100
FV (volume of sample after digestion) (ml)	100	100	100	100
DV (volume of sample aliquot submitted to digestion) (ml)	20	20	20	20
Total Amount of Hg Collected on Filter (ug)	0.000	0.030	0.025	0.018
Blank Vml (volume of reagent blank) (ml)	100	100	100	100
Blank C (solution concentration of Hg in blank) (ug Hg/L)	0	0	0	0
Blank FV (volume of blank sample after digestion) (ml)	100	100	100	100
Blank DV (volume of blank sample aliquot submitted to digestion) (ml)	20	20	20	20
Total Amount of Hg Collected in Blank(ug)	0.000	0.000	0.000	0.000

Lab Analysis Data for Analytical Fraction 2 (Front-Half Rinse)

	Run 1	Run 2	Run 3	Average
C (solution concentration of Hg in sample) (ug Hg/L)	0.02	0.03	0.04	0.03
Vml (volume of impinger plus rinses) (ml)	110	120	120	117
FV (volume of sample after digestion) (ml)	100	100	100	100
DV (volume of sample aliquot submitted to digestion) (ml)	20	20	20	20
Total Amount of Hg Collected (ug)	0.011	0.018	0.024	0.018
Blank Vml (Volume of reagent blank) (Liters)	0	0	0	0
Blank C (solution concentration of Hg in blank) (ug Hg/L)	110	110	110	110
Blank FV (volume of blank sample after digestion) (ml)	100	100	100	100
Blank DV (volume of blank sample aliquot submitted to digestion) (ml)	20	20	20	20
Total Amount of Hg Collected in Blank(ug)	0.000	0.000	0.000	0.000

Lab Analysis Data for Analytical Fraction 3 (KCl Impingers)

	Run 1	Run 2	Run 3	Average
C (solution concentration of Hg in sample) (ug Hg/L)	0.01	0.01	0.02	0.01333333
Vml (volume of impinger plus rinses) (ml)	655	721	726	701
FV (volume of sample after digestion) (ml)	100	100	100	100
DV (volume of sample aliquot submitted to digestion) (ml)	20	20	20	20
Total Amount of Hg Collected (ug)	0.033	0.036	0.073	0.047
Blank Vml (Volume of reagent blank) (Liters)	540	540	540	540
Blank C (solution concentration of Hg in blank) (ug Hg/L)	0	0	0	0
Blank FV (volume of blank sample after digestion) (ml)	100	100	100	100
Blank DV (volume of blank sample aliquot submitted to digestion) (ml)	20	20	20	20
Total Amount of Hg Collected in Blank(ug)	0.000	0.000	0.000	0.000

Lab Analysis Data for Analytical Fraction 4 (H2O2 Impingers)	Run 1	Run 2	Run 3	Average
C (solution concentration of Hg in sample) (ug Hg/L)	**0.05**	**0.07**	**0.05**	0.06
Vml (volume of impinger plus rinses) (ml)	**203**	**204**	**202**	203
FV (volume of sample after digestion) (ml)	**100**	**100**	**100**	100
DV (volume of sample aliquot submitted to digestion) (ml)	**10**	**10**	**10**	10
Total Amount of Hg Collected (ug)	0.102	0.143	0.101	0.115
Blank Vml (Volume of reagent blank) (Liters)	**202**	**202**	**202**	202
Blank C (solution concentration of Hg in blank) (ug Hg/L)	**0.04**	**0.04**	**0.04**	0.04
Blank FV (volume of blank sample after digestion) (ml)	**100**	**100**	**100**	100
Blank DV (volume of blank sample aliquot submitted to digestion) (ml)	**5**	**5**	**5**	5
Total Amount of Hg Collected in Blank(ug)	0.162	0.162	0.162	0.162

Lab Analysis Data for Analytical Fraction 5 (KMnO4 Impingers)	Run 1	Run 2	Run 3	Average
C (solution concentration of Hg in sample) (ug Hg/L)	**0.58**	**0.65**	**1.22**	0.82
Vml (volume of impinger plus rinses) (ml)	**463**	**461**	**462**	462
FV (volume of sample after digestion) (ml)	**100**	**100**	**100**	100
DV (volume of sample aliquot submitted to digestion) (ml)	**20**	**20**	**20**	20
Total Amount of Hg Collected (ug)	1.343	1.498	2.818	1.886
Blank Vml (Volume of reagent blank) (Liters)	**460**	**460**	**460**	460
Blank C (solution concentration of Hg in blank) (ug Hg/L)	**0.11**	**0.07**	**0.07**	0.08
Blank FV (volume of blank sample after digestion) (ml)	**100**	**100**	**100**	100
Blank DV (volume of blank sample aliquot submitted to digestion) (ml)	**20**	**20**	**20**	20
Total Amount of Hg Collected in Blank(ug)	0.253	0.161	0.161	0.192

Particle Bound Mercury Calculations	Run 1	Run 2	Run 3	Average
Mass of Particulate Hg Collected in the Sampling Train (µg)	0.011	0.048	0.049	0.036
Stack Gas Concentration of Particulate Hg (mg/dscm)	6.194E-06	2.096E-05	2.066E-05	1.594E-05
Stack Gas Concentration of Particulate Hg (lb/dscf)	3.867E-13	1.308E-12	1.290E-12	9.950E-13

Oxidized Mercury Calculations	Run 1	Run 2	Run 3	Average
Mass of Oxidized Hg Collected in the Sampling Train (µg)	0.033	0.036	0.073	0.047
Stack Gas Concentration of Oxidized Hg (mg/dscm)	1.844E-05	1.574E-05	3.061E-05	2.160E-05
Stack Gas Concentration of Oxidized Hg (lb/dscf)	1.151E-12	9.827E-13	1.911E-12	1.348E-12

Elemental Mercury Calculations	Run 1	Run 2	Run 3	Average
Mass of Elemental Hg Collected in the Sampling Train (µg)	1.030	1.318	2.597	1.648
Stack Gas Concentration of Elemental Hg (mg/dscm)	5.798E-04	5.757E-04	1.095E-03	7.501E-04
Stack Gas Concentration of Elemental Hg (lb/dscf)	3.619E-11	3.594E-11	6.835E-11	4.683E-11

Total Mercury Calculations	Run 1	Run 2	Run 3	Average
Mass of Total Hg Collected in the Sampling Train (µg)	1.073	1.403	2.718	1.731
Stack Gas Concentration of Total Hg (mg/dscm)	6.044E-04	6.124E-04	1.146E-03	7.876E-04
Stack Gas Concentration of Total Hg (lb/dscf)	3.773E-11	3.823E-11	7.155E-11	4.917E-11
Volume of Gas Sample as Measured by the Dry Gas Meter Corrected to Dry Standard Conditions (dscm)	1.776	2.290	2.372	2.146

MEASURED DATA FROM TEST RUNS

Point Count	Run #	Run Time (min)	Pitot Delta P (in H2O)	Square Root of Delta P	Orifice Delta H (in H2O)	DGM Temp OUT (°F)	Average DGM Temp (°F)	Stack Pressure (in H2O)	Stack Temp (°F)
1	1	**0**	**0.020**	0.141	**0.90**	**71**	71.00	**-13**	**101**
2	1	**5**	**0.020**	0.141	**0.90**	**72**	72.00		**134**
3	1	**10**	**0.020**	0.141	**0.90**	**72**	72.00		**138**
4	1	**15**	**0.010**	0.100	**0.45**	**73**	73.00		**148**
5	1	**20**	**0.015**	0.122	**0.68**	**74**	74.00		**163**
6	1	**25**	**0.015**	0.122	**0.68**	**75**	75.00		**164**
7	1	**30**	**0.010**	0.100	**0.45**	**76**	76.00		**164**
8	1	**35**	**0.010**	0.100	**0.45**	**76**	76.00		**164**
9	1	**40**	**0.009**	0.095	**0.41**	**78**	78.00		**164**
10	1	**45**	**0.009**	0.095	**0.41**	**78**	78.00		**165**
11	1	**50**	**0.009**	0.095	**0.41**	**79**	79.00		**165**
12	1	**55**	**0.009**	0.095	**0.41**	**79**	79.00		**165**
13	1	**60**	**0.006**	0.077	**0.34**	**80**	80.00		**157**
14	1	**65**	**0.007**	0.084	**0.40**	**80**	80.00		**164**
15	1	**70**	**0.007**	0.084	**0.40**	**81**	81.00		**164**
16	1	**75**	**0.007**	0.084	**0.40**	**81**	81.00		**165**
17	1	**80**	**0.008**	0.089	**0.45**	**82**	82.00		**166**
18	1	**85**	**0.008**	0.089	**0.45**	**83**	83.00		**166**
19	1	**90**	**0.008**	0.089	**0.45**	**83**	83.00		**167**
20	1	**95**	**0.009**	0.095	**0.51**	**84**	84.00		**166**
21	1	**100**	**0.009**	0.095	**0.51**	**84**	84.00		**166**
22	1	**105**	**0.010**	0.100	**0.56**	**84**	84.00		**156**
23	1	**110**	**0.010**	0.100	**0.56**	**85**	85.00		**146**
24	1	**115**	**0.010**	0.100	**0.56**	**85**	85.00		**146**
25	1	**120**	**0.006**	0.077	**0.34**	**86**	86.00		**106**
26	1	**125**	**0.006**	0.077	**0.34**	**86**	86.00		**109**
27	1	**130**	**0.007**	0.084	**0.43**	**87**	87.00		**117**
28	1	**135**	**0.007**	0.084	**0.43**	**87**	87.00		**140**
29	1	**140**	**0.009**	0.095	**0.55**	**87**	87.00		**167**
30	1	**145**	**0.010**	0.100	**0.62**	**88**	88.00		**167**
31	1	**150**	**0.010**	0.100	**0.62**	**88**	88.00		**166**
32	1	**155**	**0.010**	0.100	**0.62**	**88**	88.00		**166**
33	1	**160**	**0.010**	0.100	**0.62**	**88**	88.00		**166**
34	1	**165**	**0.006**	0.077	**0.34**	**88**	88.00		**165**
35	1	**170**	**0.006**	0.077	**0.34**	**89**	89.00		**163**
36	1	**175**	**0.006**	0.077	**0.34**	**89**	89.00		**163**
37	1								
38	1								
39	1								
40	1								
41	1								
42	1								
43	1								
44	1								
45	1								
46	1								
47	1								
48	1								

Point Count	Run #	Run Time (min)	Pitot Delta P (in H2O)	Square Root of Delta P	Orifice Delta H (in H2O)	DGM Temp OUT (°F)	Average DGM Temp (°F)	Stack Pressure (in H2O)	Stack Temp (°F)
49	2	**0**	**0.010**	0.100	**0.56**	**88**	88.00		**117**
50	2	**5**	**0.010**	0.100	**0.56**	**88**	88.00		**115**
51	2	**10**	**0.010**	0.100	**0.56**	**89**	89.00		**114**
52	2	**15**	**0.010**	0.100	**0.56**	**89**	89.00		**152**
53	2	**20**	**0.010**	0.100	**0.56**	**89**	89.00		**165**
54	2	**25**	**0.010**	0.100	**0.56**	**89**	89.00		**165**
55	2	**30**	**0.010**	0.100	**0.56**	**89**	89.00		**165**
56	2	**35**	**0.009**	0.095	**0.51**	**90**	90.00		**165**
57	2	**40**	**0.009**	0.095	**0.51**	**90**	90.00		**165**
58	2	**45**	**0.009**	0.095	**0.51**	**90**	90.00		**166**
59	2	**50**	**0.010**	0.100	**0.56**	**90**	90.00		**165**
60	2	**55**	**0.009**	0.095	**0.51**	**90**	90.00		**166**
61	2	**60**	**0.009**	0.095	**0.51**	**90**	90.00		**152**
62	2	**65**	**0.007**	0.084	**0.40**	**90**	90.00		**164**
63	2	**70**	**0.007**	0.084	**0.40**	**90**	90.00		**165**
64	2	**75**	**0.007**	0.084	**0.40**	**90**	90.00		**165**
65	2	**80**	**0.007**	0.084	**0.40**	**90**	90.00	**-13.7**	**165**
66	2	**85**	**0.007**	0.084	**0.40**	**90**	90.00		**165**
67	2	**90**	**0.007**	0.084	**0.40**	**90**	90.00		**165**
68	2	**95**	**0.007**	0.084	**0.40**	**90**	90.00		**165**
69	2	**100**	**0.009**	0.095	**0.51**	**90**	90.00		**167**
70	2	**105**	**0.009**	0.095	**0.51**	**90**	90.00		**153**
71	2	**110**	**0.009**	0.095	**0.51**	**89**	89.00		**137**
72	2	**115**	**0.009**	0.095	**0.51**	**89**	89.00		**147**
73	2	**120**	**0.006**	0.077	**0.26**	**89**	89.00		**154**
74	2	**125**	**0.005**	0.071	**0.22**	**89**	89.00		**163**
75	2	**130**	**0.006**	0.077	**0.26**	**89**	89.00		**163**
76	2	**135**	**0.006**	0.077	**0.26**	**89**	89.00		**165**
77	2	**140**	**0.006**	0.077	**0.26**	**89**	89.00		**165**
78	2	**145**	**0.007**	0.084	**0.24**	**90**	90.00	**-13.2**	**165**
79	2	**150**	**0.009**	0.095	**0.31**	**90**	90.00		**167**
80	2	**155**	**0.009**	0.095	**0.31**	**90**	90.00		**166**
81	2	**160**	**0.009**	0.095	**0.31**	**90**	90.00		**166**
82	2	**165**	**0.008**	0.089	**0.28**	**91**	91.00		**128**
83	2	**170**	**0.008**	0.089	**0.28**	**90**	90.00		**116**
84	2	**175**	**0.007**	0.084	**0.24**	**91**	91.00		**116**
85	2	**180**	**0.009**	0.095	**0.31**	**91**	91.00		**115**
86	2	**185**	**0.009**	0.095	**0.31**	**91**	91.00		**155**
87	2	**190**	**0.008**	0.089	**0.28**	**91**	91.00		**165**
88	2	**195**	**0.007**	0.084	**0.24**	**90**	90.00		**164**
89	2	**200**	**0.009**	0.095	**0.42**	**90**	90.00		**148**
90	2	**205**	**0.009**	0.095	**0.42**	**90**	90.00		**165**
91	2	**210**	**0.010**	0.100	**0.46**	**90**	90.00		**167**
92	2	**215**	**0.011**	0.105	**0.51**	**90**	90.00		**133**
93	2	**220**	**0.007**	0.084	**0.32**	**90**	90.00		**106**
94	2	**225**	**0.008**	0.089	**0.37**	**90**	90.00		**130**
95	2	**230**	**0.007**	0.084	**0.32**	**90**	90.00		**154**
96	2	**235**	**0.006**	0.077	**0.28**	**90**	90.00		**165**

Point Count	Run #	Run Time (min)	Pitot Delta P (in H2O)	Square Root of Delta P	Orifice Delta H (in H2O)	DGM Temp OUT (°F)	Average DGM Temp (°F)	Stack Pressure (in H2O)	Stack Temp (°F)
97	3	0	0.010	0.100	0.46	85	85.00	-14	129
98	3	5	0.010	0.100	0.46	86	86.00		165
99	3	10	0.010	0.100	0.46	86	86.00		165
100	3	15	0.010	0.100	0.47	86	86.00		165
101	3	20	0.007	0.084	0.33	86	86.00		165
102	3	25	0.007	0.084	0.33	86	86.00		165
103	3	30	0.008	0.089	0.38	87	87.00		165
104	3	35	0.009	0.095	0.42	87	87.00		165
105	3	40	0.008	0.089	0.38	87	87.00		165
106	3	45	0.008	0.089	0.38	87	87.00		165
107	3	50	0.008	0.089	0.38	88	88.00		165
108	3	55	0.008	0.089	0.38	88	88.00		165
109	3	60	0.009	0.095	0.42	88	88.00		165
110	3	65	0.009	0.095	0.42	88	88.00		153
111	3	70	0.007	0.084	0.33	87	87.00		151
112	3	75	0.009	0.095	0.42	87	87.00		151
113	3	80	0.009	0.095	0.42	88	88.00		151
114	3	85	0.017	0.130	0.80	87	87.00		141
115	3	90	0.013	0.114	0.60	87	87.00		156
116	3	95	0.013	0.114	0.60	87	87.00		157
117	3	100	0.015	0.122	0.71	87	87.00		164
118	3	105	0.015	0.122	0.71	86	86.00		167
119	3	110	0.015	0.122	0.71	86	86.00		167
120	3	115	0.015	0.122	0.71	87	87.00		167
121	3	120	0.015	0.122	0.71	86	86.00		166
122	3	125	0.012	0.110	0.56	86	86.00		166
123	3	130	0.011	0.105	0.52	86	86.00		166
124	3	135	0.011	0.105	0.52	86	86.00		166
125	3	140	0.010	0.100	0.47	86	86.00		165
126	3	145	0.010	0.100	0.47	86	86.00		165
127	3	150	0.010	0.100	0.47	86	86.00		165
128	3	155	0.010	0.100	0.47	86	86.00		165
129	3	160	0.007	0.084	0.33	86	86.00		135
130	3	165	0.007	0.084	0.33	86	86.00		160
131	3	170	0.008	0.089	0.38	86	86.00		162
132	3	175	0.005	0.071	0.23	86	86.00		162
133	3	180	0.007	0.084	0.33	86	86.00		164
134	3	185	0.006	0.077	0.28	86	86.00		165
135	3	190	0.006	0.077	0.28	86	86.00		165
136	3	195	0.007	0.084	0.33	86	86.00	-14.2	166
137	3	200	0.008	0.089	0.38	86	86.00		166
138	3	205	0.008	0.089	0.38	85	85.00		167
139	3	210	0.009	0.095	0.42	85	85.00		167
140	3	215	0.009	0.095	0.42	85	85.00		167
141	3	220	0.009	0.095	0.42	85	85.00		167
142	3	225	0.007	0.084	0.33	85	85.00		122
143	3	230	0.007	0.084	0.33	85	85.00		119
144	3	235	0.005	0.071	0.23	85	85.00		118

EPA Methods 1, 2, 3, 4, and PRE 003
Nomenclature and Sample Calculations
ECO Exhaust Duct - Run 3

Constants

$CO2F_{wt} := 44$ $O2F_{wt} := 32$ $CON2F_{wt} := 28$ $H2OF_{wt} := 18$ $in\_wg := 0.073529 \cdot in\_Hg$ $gr := \frac{lb}{7000}$

$mmBtu := 1 \cdot 10^6 \cdot BTU$ $CF_{wt} := 12.011$ $NO2F_{wt} := 46.005$ $COF_{wt} := 28.01$ $H2SO4F_{wt} := 98.0756$ $F := R$

$HClF_{wt} := 36.46$ $SO2F_{wt} := 64.0628$

Measured Stack Variables

$A := 4 \cdot ft^2$	stack cross-sectional area (ft^2)
$C_p := .84$	pitot tube coefficient (dimensionless)
$P_{bar} := 29.15 \cdot in\_Hg$	barometric pressure (in. Hg)
$\theta := 240 \cdot min$	net run time (minutes)
$\%CO_2 := 9.17$	percent CO_2 by volume (dry basis) (dimensionless)
$\%O_2 := 9.83$	percent O_2 by volume (dry basis) (dimensionless)
$\%CO := 0.0$	percent CO by volume (dry basis) (dimensionless)
$\%N_2 := 81.0$	percent N_2 by volume (dry basis) (dimensionless)
$P_g := -14.1 \cdot in\_wg$	flue gas static pressure (in. H_2O)
$P_{std} := 29.92 \cdot in\_Hg$	standard absolute pressure at 29.92 inches of Hg
$T_m := 546.271 \cdot R$	dry gas meter temperature (460 R + t_m °F) (Rankine)
$T_{savg} := 618.96 \cdot R$	average absolute flue gas temperature (460 R + t_{savg} °F) (Rankine)
$T_{std} := 528 \cdot R$	standard absolute temperature (460 R + t_{std} °F) (Rankine)
$\Delta H := .4431 \cdot in\_wg$	average pressure differential of orifice meter (in_wg)
$SQ\Delta P_{avg} := .09612^2 \cdot in\_wg$	square of <u>average square root ΔP</u> [(in_wg)]
$V_m := 87.86 \cdot ft^3$	volume of metered gas sample (dry actual cubic feet)
$\gamma := 1.0112$	gamma, dry gas meter calibration factor (dimensionless)
$NOZDIA := .503 \cdot in$	sampling nozzle diameter (in.)
$V_{lc} := 297.6 \cdot mL$	total volume of liquid collected in impingers and silica gel (1g = 1ml)

$mgquanHg := 0.002718 \cdot mg$ total Hg catch mass (mg)

Calculated Stack Variables

Volume of dry gas sampled at standard conditions, (dscf)

$$V_{mstd} := \gamma \cdot V_m \cdot \frac{P_{bar} + \Delta H}{P_{std}} \cdot \frac{T_{std}}{T_m}$$

$$V_{mstd} = 83.756\ ft^3$$

Volume of water vapor at standard conditions (68 °F, scf)

$$V_{wstd} := \frac{0.04707 \cdot ft^3}{mL} \cdot V_{lc}$$

$$V_{wstd} = 14.008\ ft^3$$

Percent moisture by volume as measured in flue gas

$$\%H2O := (100) \cdot \frac{V_{wstd}}{V_{wstd} + V_{mstd}}$$

$$\%H2O = 14.33$$

Absolute flue gas pressure (in. Hg)

$$P_s := P_{bar} + P_g$$

$$P_s = 28.11 \cdot in\_Hg$$

Dry mole fraction of flue gas (dimensionless)

$$M_{fd} := 1 - \frac{\%H2O}{100}$$

$$M_{fd} = 0.857$$

Dry molecular weight of flue gas (lb/lb-mole)

$$M_d := \frac{\%CO_2}{100} \cdot CO2F_{wt} + \frac{\%O_2}{100} \cdot O2F_{wt} + \frac{100 - \%CO_2 - \%O_2}{100} \cdot CON2F_{wt}$$

$$M_d = 29.86$$

Wet molecular weight of flue gas (lb/lb-mole)

$$M_s := M_d \cdot M_{fd} + H2OF_{wt} \cdot \frac{\%H2O}{100}$$

$$M_s = 28.16$$

Average flue gas velocity (NB: ΔP_{avg} is square of average square root) (ft/sec)

$$v_s := 85.49 \cdot \frac{ft}{sec} \cdot \left(\frac{in\_Hg}{R \cdot in\_wg}\right)^{0.5} \cdot C_p \cdot \sqrt{SQ\Delta P_{avg}} \cdot \sqrt{\frac{T_{savg}}{P_s \cdot M_s}}$$

$$v_s = 6.1\ ft \cdot sec^{-1}$$

Wet volumetric flue gas flow rate at actual conditions (acfm)

$$Q_{aw} := v_s \cdot A$$

$$Q_{aw} = 1465 \frac{ft^3}{min}$$

Dry volumetric flue gas flow rate at standard conditions (dscfm)

$$Q_{sd} := M_{fd} \cdot v_s \cdot A \cdot \frac{T_{std}}{T_{savg}} \cdot \frac{P_s}{P_{std}}$$

$$Q_{sd} = 1006 \frac{ft^3}{min}$$

Dry air flow rate at standard conditions (lb/hr)

$$Q_{lb} := \frac{Q_{sd} \cdot M_d \cdot lb}{385.3 \cdot ft^3}$$

$$Q_{lb} = 4.677 \cdot 10^3 \frac{lb}{hr}$$

Isokinetic Calculations

Percent isokinetic of sampling rate (%)

$$\%I := \frac{P_{std}}{T_{std}} \cdot \frac{T_{savg}}{P_s} \cdot \left[\frac{V_{mstd}}{v_s \cdot M_{fd} \cdot \theta \cdot \pi \cdot \left(\frac{NOZDIA}{2}\right)^2} \right]$$

$\%I = 100.6 \%$

Total Hg concentration (mg/dscm)

$$ConcHgmgcm := \frac{mgquanHg}{V_{mstd}}$$

$$ConcHgmgcm = 1.15 \cdot 10^{-3} \frac{mg}{m^3}$$

Total Hg mass emission rate (lb/hr)

$$HgEMRlbhr := \frac{mgquanHg}{V_{mstd}} \cdot Q_{sd}$$

$$HgEMRlbhr = 4.32 \cdot 10^{-6} \frac{lb}{hr}$$

First Analytical Laboratories

ANALYSIS REPORT

Mercury
Ontario-Hydro Method

Project #020301

Prepared for:

Air Compliance Testing
9438 Akins Road
Cleveland, OH 44133

Reviewed and Approved by:

WHWadlin

William H. Wadlin, Ph. D.
Laboratory Manager

May 20, 2002

First Analytical Laboratories

CASE NARRATIVE

Project #: 20506
Client: Air Compliance Testing
Client Project ID: 020301

Report Date: 20-May-02

Samples:

Seven sets of samples were submitted, one of which was the blank set. These samples required determination of mercury by the Ontario Hydro Method. All of the samples were received in good condition, with no leakage.

Preparation:

The samples were prepared and analyzed according to the Ontario Hydro Method.

Analysis:

Mercury was determined by Cold Vapor Atomic Absorption Spectrophotometry (CVAA). According to the client's request, the largest possible aliquots were used for this analysis to obtain the lowest possible detection limit. For most of the analyses, 20 ml aliquots were used as compared to the usual 5 ml aliquots. The upper limits of aliquot size were determined either by the amount of sample available (as with container 2), or analytical problems related to high reagent concentration (as with containers 1,3 and 4).

Results:

The results are presented as total micrograms of mercury present in the whole analytical fraction indicated. Mercury was not detected in the blanks or in any of the Containers 4 (hydrogen peroxide impingers). In the B series mercury was only measurable in container 5.

Quality Control:

Mercury was not detected in the blanks. The spike recovery was within the normal range of 70% to 130%. Each sample was analyzed in duplicate. All of the replicates agreed within 10%. The RSD of the triplicates were also within the acceptable range.

First Analytical Laboratories
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ANALYSIS REPORT

Project #: 20506
Client: Air Compliance Testing, Inc.
Client Project ID: 020301

Report Date: 20-May-02
Date Received: 15-May-02

Total Micrograms of Mercury in Analytical Fraction

Sample	Cont 1	Cont 2	Cont 3	Cont 4	Cont 5	Total
020301A-BL	<0.10	<0.11	<0.54	<0.81	<0.46	<2.02
020301A-1	0.9	0.4	8.9	<0.41	0.5	10.7
020301A-2	1.3	0.7	14.6	<0.42	<0.46	16.6
020301A-3	0.4	0.3	13.5	<0.42	0.8	15.0
020301B-1	<0.10	<0.11	<0.65	<0.41	1.3	1.3
020301B-2	<0.10	<0.12	<0.72	<0.41	1.5	1.5
020301B-3	<0.10	<0.12	<0.73	<0.40	2.8	2.8

QC SUMMARY

Back Spike, %Recov. 100%

MERCURY

CVAA ANALYSIS RUN SUMMARY AND CALCULATION WORKSHEET

Client: Air Compliance Testing, Inc.
Proj #: 20506
Date: 16-May-02

IDL = 0.2 µg/L
Postdig'n spike conc. = 5.0 µg/L

Sample ID Client	FAL	Test Sol'n µg/L	Dig'te Conc µg/L	FV ml	Dil'n Factor	Volume ml	Digst'd Vol. ml		Total µg
CONTAINER 1 &12									
020301A-BL-12	20506.B-12	0.07	0.07	100	1	100	20	<	0.10
020301A-1-F	20506.A1-1	1.73	1.73	100	1	100	20		0.87
020301A-2-F	20506.A2-1	2.65	2.65	100	1	100	20		1.33
020301A-3-F	20506.A3-1	0.87	0.87	100	1	100	20		0.43
020301B-1-F	20506.B1-1	-0.04	-0.04	100	1	100	20	<	0.10
020301B-2-F	20506.B2-1	0.06	0.06	100	1	100	20	<	0.10
020301B-3-F	20506.B3-1	0.05	0.05	100	1	100	20	<	0.10
CONTAINER 2 & 7									
020301A-BL-7	20506.B-7	0.02	0.02	100	1	110	20	<	0.11
020301A-1-FH	20506.A1-2	0.67	0.67	100	1	120	20		0.40
020301A-2-FH	20506.A2-2	1.21	1.21	100	1	120	20		0.73
020301A-3-FH	20506.A3-2	0.40	0.40	100	1	170	20		0.34
020301B-1-FH	20506.B1-2	0.02	0.02	100	1	110	20	<	0.11
020301B-2-FH	20506.B2-2	0.03	0.03	100	1	120	20	<	0.12
020301B-3-FH	20506.B3-2	0.04	0.04	100	1	120	20	<	0.12
CONTAINER 3 & 8									
020301A-BL-8	20506.B-8	0.02	0.02	100	1	540	20	<	0.54
020301A-1-BH	20506.A1-3	3.23	3.23	100	1	553	20		8.92
020301A-2-BH	20506.A2-3	5.16	5.16	100	1	566	20		14.59
020301A-3-BH	20506.A3-3	5.02	5.02	100	1	540	20		13.54
020301B-1-BH	20506.B1-3	0.01	0.01	100	1	655	20	<	0.65
020301B-2-BH	20506.B2-3	0.00	0.00	100	1	721	20	<	0.72
020301B-3-BH	20506.B3-3	0.02	0.02	100	1	726	20	<	0.73
CONTAINER 4 & 9									
020301A-BL-9	20506.B-9	0.04	0.04	100	1	202	5	<	0.81
020301A-1-IM4	20506.A1-4	0.07	0.07	100	1	207	10	<	0.41
020301A-2-IM4	20506.A2-4	0.01	0.01	100	1	212	10	<	0.42
020301A-3-IM4	20506.A3-4	0.00	0.00	100	1	209	10	<	0.42
020301B-1-IM4	20506.B1-4	0.05	0.05	100	1	203	10	<	0.41
020301B-2-IM4	20506.B2-4	0.07	0.07	100	1	204	10	<	0.41
020301B-3-IM4	20506.B3-4	0.05	0.05	100	1	202	10	<	0.40

BACK SPK 20506.A1-4S 5.00 %REC = 99.9%

MERCURY

CVAA ANALYSIS RUN SUMMARY AND CALCULATION WORKSHEET

Client: Air Compliance Testing, Inc.
Proj. #: 20506
Date: 16-May-02

IDL = 0.2 µg/L
Postdig'n spike conc. = 5.0 µg/L

Sample ID Client	FAL	Test Sol'n µg/L	Dig'te Conc µg/L	FV ml	Dil'n Factor	Volume ml	Digst'd Vol. ml		Total µg
CONTAINER 5, 10 & 11									
020301A-BL-10	20506.B-10	0.11	0.11	100	1	460	20	<	0.46
020301A-BL-10a	20506.B-10a	0.07	0.07	100	1	460	20	<	0.46
020301A-BL-10b	20506.B-10b	0.03	0.03	100	1	460	20	<	0.46
020301A-BL-11	20506.B-11	0.04	0.04	100	1	460	10	<	0.92
020301A-1-IM567	20506.A1-5	0.23	0.23	100	1	460	20		0.52
020301A-2-IM567	20506.A2-5	0.17	0.17	100	1	464	20	<	0.46
020301A-3-IM567	20506.A3-5	0.36	0.36	100	1	463	20		0.83
020301B-1-IM567	20506.B1-5	0.58	0.58	100	1	463	20		1.33
020301B-2-IM567	20506.B2-5	0.65	0.65	100	1	461	20		1.49
020301B-3-IM567	20506.B3-5	1.22	1.22	100	1	462	20		2.82

Calibration Data

	True conc., µg/L	Abs.
Blank	0.00	0.000
Standard 1	0.50	0.014
Standard 2	1.00	0.027
Standard 3	2.00	0.052
Standard 4	5.00	0.130
Standard 5	10.00	0.241

Calibration Verifications

ICV = 5	4.79	CCV4 = 5	5.06
ICB = 0	0.00	CCB4 = 0	0.06
CCV1 = 5	4.91	CCV5 = 5	4.94
CCB1 = 0	0.03	CCB5 = 0	0.04
CCV2 = 5	5.05	CCV6 = 5	4.83
CCB2 = 0	0.10	CCB6 = 0	0.03
CCV3 = 5	4.84		
CCB3 = 0	0.06		

Ontario Hydro First Analytical Laboratories

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Tel. (919) 942-8607
FAX (919) 929-8688

Air Compliance Testing Project # 020301
Date Shipped: 5/14/02
Shipper: Fed Ex
Airbill #: 8335 9370 0110

P.O. # 020301

Chain of Custody Record

Sample #	Run #	Contnr. #	Matrix	Comments
020301A - 1 - F	1	1	Quartz Filter	Analyze all samples for Particle-Bound Hg
020301A - 2 - F	2	1	Quartz Filter	as per sec 13.4 of Ontario Hydro Method
020301A - 3 - F	3	1	Quartz Filter	"
020301A - 1 - FH	1	2	120 ~~100~~ ml HNO_3	"
020301A - 2 - FH	2	2	120 ~~100~~ ml HNO_3	"
020301A - 3 - FH	3	2	170 ~~120~~ ~~100~~ ml HNO_3 RP	"
020301A - 1 - BH	1	3	102.5 ml H_2O, 300ml KCl, 150 ml HNO_3	Combine run specific containers analyze all samples for Oxidized Hg
020301A - 1a - BH	1	3	"	as per sec 13.4 of Ontario Hydro Method
020301A - 2 - BH	2	3	116.2 ml H_2O, 300ml KCl, 150 ml HNO_3	"
020301A - 2a - BH	2	3	"	"
020301A - 3 - BH	3	3	89.3 ml H_2O, 300ml KCl, 150 ml HNO_3	"
020301A - 3a - BH	3	3	"	"
020301A - 1 - IM4	1	4	7.3 ml H_2O 100ml HNO_3 / H_2O_2 100 ml HNO_3	Analyze all samples for Elemental Hg as per sec 13.4 of Ontario Hydro Method.
020301A - 2 - IM4	2	4	11.5 ml H_2O 100ml HNO_3 / H_2O_2 100 ml HNO_3	**NOTE: Low Elemental Hg concentrations expected. Please submit large aliquot volumes for analysis.**
020301A - 3 - IM4	3	4	9.1 ml H_2O 100ml HNO_3 / H_2O_2 100 ml HNO_3	"

Received By:	Relinquished By:	Date:	Notes:
			Call Rob Lisy @ (440) 230-1100
Nod[illegible]		5/15/02	For any questions.

Air Compliance Testing, Inc.
(Ontario Hydro.xls-First Analytical Laboratories) 5/14/2002

Job Number: 020301A
Done By / Date: RL / 5/14/02
Final Check By / Date: ______ / ______

Ontario Hydro First Analytical Laboratories

First Analytical Laboratories
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Tel. (919) 942-8607
FAX (919) 929-8688

Air Compliance Testing Project # 020301
Date Shipped:
Shipper: Fed Ex
Airbill #:

P.O. # 020301

Chain of Custody Record

Sample #	Run #	Contnr. #	Matrix	Comments
020301B - 1 - F	1	1	Quartz Filter	Analyze all samples for Particle-Bound Hg
020301B - 2 - F	2	1	Quartz Filter	as per sec 13.4 of Ontario Hydro Method
020301B - 3 - F	3	1	Quartz Filter	"
020301B - 1 - FH	1	2	110 ~~100~~ ml HNO_3	"
020301B - 2 - FH	2	2	120 ~~100~~ ml HNO_3	"
020301B - 3 - FH	3	2	120 ~~100~~ ml HNO_3	"
020301B - 1 - BH	1	3	204.7 ml H_2O, 300ml KCl, 150 ml HNO_3	Combine run specific containers analyze all samples for Oxidized Hg
020301B - 1a - BH	1	3	"	as per sec 13.4 of Ontario Hydro Method
020301B - 2 - BH	2	3	270.8 ml H_2O, 300ml KCl, 150 ml HNO_3	"
020301B - 2a - BH	2	3	"	"
020301B - 3 - BH	3	3	276.2 ml H_2O, 300ml KCl, 150 ml HNO_3	"
020301B - 3a - BH	3	3	"	"
020301B - 1 - IM4	1	4	29 ml H_2O 100ml HNO_3 / H_2O_2 100 ml HNO_3	Analyze all samples for Elemental Hg as per sec 13.4 of Ontario Hydro Method.
020301B - 2 - IM4	2	4	38 ml H_2O 100ml HNO_3 / H_2O_2 100 ml HNO_3	**NOTE: Low Elemental Hg concentrations expected. Please submit large aliquot volumes for analysis.**
020301B - 3 - IM4	3	4	22 ml H_2O 100ml HNO_3 / H_2O_2 100 ml HNO_3	"

Received By:	Relinquished By:	Date:	Notes:
			Call Rob Lisy @ (440) 230-1100
Wadi		5/15/02	For any questions.

Job Number: 020301B
Done By / Date: [illegible] / 5/1/02
Final Check By / Date: ______ / ______

Ontario Hydro 1st Analytical Laboratories

First Analytical Laboratories
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Chapel Hill, NC 27514
Tel. (919) 942-8607
FAX (919) 929-8688

Air Compliance Testing Project # 020301
Date Shipped:
Shipper: Fed Ex
Airbill #:

P.O. # 020301

Chain of Custody Record

Sample #	Run #	Contnr. #	Matrix	Comments
020301A - 1 - IM567	1	5	0.1 ml H_2O 300ml $KMnO_4$ 160 ml HNO_3	Analyze all samples for Elemental Hg as per sec 13.4 of Ontario Hydro Method.
020301A - 2 - IM567	2	5	3.5 ml H_2O 300ml $KMnO_4$ 160 ml HNO_3	**NOTE: Low Elemental Hg concentrations expected. Please submit large aliquot volumes for analysis.**
020301A - 3 - IM567	3	5	2.6 ml H_2O 300ml $KMnO_4$ 160 ml HNO_3	"
020301A - BL - 7	BLANK	7	0.1N HNO_3	**Analyze as Blanks**
020301A - BL - 8	BLANK	8	1.0N KCl	"
020301A - BL - 9	BLANK	9	5%HNO_3/10%H_2O_2	"
020301A - BL - 10	BLANK	10	$KMnO_4$	Have 10, 10a, 10b"
020301A - BL - 10 - 2	BLANK	10	$KMnO_4$	"
020301A - BL - 11	BLANK	11	Hydroxylamine Hydrochloride	"
020301A - BL - 12	BLANK	12	3 Quartz Filters	"

Received By:	Relinquished By:	Date:	Notes:
			Call Rob Lisy @ (440) 230-1100
Wade		5/15/02	For any questions.

Job Number: 020301A
Done By / Date: KR / 5/15/02
Final Check By / Date: ______ / ______

Air Compliance Testing, Inc.
(Ontario Hydro.xls-1st Analytical Laboratories) 5/14/2002

Ontario Hydro 1st Analytical Laboratories

First Analytical Laboratories
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˘hapel Hill, NC 27514
Tel. (919) 942-8607
FAX (919) 929-8688

Air Compliance Testing Project # 020301
Date Shipped:
Shipper: Fed Ex
Airbill #:

P.O. # 020301

Chain of Custody Record

Sample #	Run #	Contnr. #	Matrix	Comments
020301B - 1 - IM567	1	5	3.1 ml H_2O 300ml $KMnO_4$ 160 ml HNO_3	Analyze all samples for Elemental Hg as per sec 13.4 of Ontario Hydro Method.
020301B - 2 - IM567	2	5	1.4 ml H_2O 300ml $KMnO_4$ 160 ml HNO_3	**NOTE: Low Elemental Hg concentrations expected. Please submit large aliquot volumes for analysis.**
020301B - 3 - IM567	3	5	25 ml H_2O 300ml $KMnO_4$ 160 ml HNO_3	"

Received By:	Relinquished By:	Date:	Notes:
W. [signature]		5/15/02	Call Rob Lisy @ (440) 230-1100 For any questions.

Job Number: 020301 B
Done By / Date: KF / 5/17/02
Final Check By / Date: ____ / ____

Ontario Hydro Filter Record of Custody

ion Container Number: 002

Seal I.D. no.		Full Signature	Date	Time	Reason for Breaking Seal	Final Vol. ml	Filter Number
020301A - 1 - F	S	KSI Kevin C Ruff	5 2 02	14 45	Recovery		–
	B	Kevin C Ruff	5 14 02	1040			
020301A - 1 - F	S	Kevin C Ruff	5 14 02	10 53			
	B						
	S						
	B						
020301A - 2 - F	S	KSI Kevin C Ruff	5 2 02	14 50	Recovery		–
	B	Kevin C Ruff	5 14 02	1106			
020301A - 2 - F	S	Kevin C Ruff	5 14 02	11 11			
	B						
	S						
	B						
020301A - 3 - F	S	KSI Kevin C Ruff	5 2 02	14 54	Recovery		–
	B	Kevin C Ruff	5 14 02	1129			
020301A - 3 - F	S	Kevin C Ruff	5 14 02	1135			
	B						
	S						
	B						
020301A - 4 - F	S						
	B						
020301A - 4 - F	S						
	B						
	S						
	B						

Were all seals intact?____Yes _____No (Describe seal and reasoning in the "Remarks")

Were all liquid levels at marked levels?______Yes _______No (Estimate loss in the "Remarks")

Received By Sample Custodian ____________ ________ ________

(Full Signature) (Date) (Time)

Remarks: ______________________________

Job Number: 020301A

Done By / Date: KR / 5 14 02

Final Check By / Date: ______ / ______

Ontario Hydro FH Record of Custody

ation Container Number: 601

Seal I.D. no.		Full Signature	Date	Time	Reason for Breaking Seal	Final Vol. ml
020301A - 1 - FH	S	[signature]	5-9-02	856	FH Filter Rinse	100 ml HNO_3 .1N
	B	[signature]	5-14-02	1041		
020301A - 1 - FH	S	[signature]	5-14-02	1052		+20 ml HNO_3 .1N
	B					
	S					
	B					
020301A - 2 - FH	S	[signature]	5-13-02	1315		100 ml HNO_3
	B	[signature]	5-14-02	1102		
020301A - 2 - FH	S	[signature]	5-14-02	1112		+20 ml HNO_3 .1N
	B					
	S					
	B					
020301A - 3 - FH	S	[signature]	5-13-02	1150		KR ~~100~~ 150 ml HNO_3
	B	[signature]	5-14-02	1125		
020301A - 3 - FH	S	[signature]	5-14-02	1136		+20 ml HNO_3 .1N
	B					
	S					
	B					
020301A - 4 - FH	S					ml HNO_3
	B					
020301A - 4 - FH	S					ml HNO_3
	B					
	S					
	B					

Were all seals intact? ____Yes _____No (Describe seal and reasoning in the "Remarks")

Were all liquid levels at marked levels? ______Yes _______No (Estimate loss in the "Remarks")

Received By Sample Custodian ____________ ________ ________

(Full Signature) (Date) (Time)

Remarks: ____________________

Job Number: 020301A

Done By / Date: TS / 5-9-02

Final Check By / Date: ______ / ______

Ontario Hydro BH Record of Custody

:ion Container Number: 001

Seal I.D. no.		Full Signature	Date	Time	Reason for Breaking Seal	Final Vol. ml
020301A - 1 - BH	S	Jate Strohle	5.9.02	857	addition of 5% KMnO4 @ 1439	102.5 ml H_2O 300ml KCl 150 ml HNO_3
	B	Ken C Ruff	51302	1434		
020301A - 1a - BH	S	Jate Strohle	5.9.02	857	addition of 5% KMnO4 @ 1439	___ ml H_2O 300ml KCl 150 ml HNO_3
	B	Ken C Ruff	51302	1435		
	S					
	B					
020301A - 2 - BH	S	Jate Strohle	5/10/02	1430	addition of 5% KMnO4 @ 1440	116.2 ml H_2O 300ml KCl 150 ml HNO_3
	B	Ken C Ruff	51302	1435		
020301A - 2 - BH	S	Jate Strohle	51002	1431	addition of 5% KMnO4 @ 1440	— ml H_2O 300ml KCl 150 ml HNO_3
	B	Ken C Ruff	51302	1435		
	S					
	B					
020301A - 3a - BH	S	Ken C Ruff	51302	1648	BH Filter Rinse	39.8 ml H_2O 300ml KCl 150 ml HNO_3
	B	Ken C Ruff	51402	1126		
020301A - 3b - BH	S	Ken C Ruff	51302	1648		___ ml H_2O 300ml KCl 150 ml HNO_4
	B					
020301A - 1a - BH	S	Ken C Ruff	51302	1651	BH Rinse Filter	
	B	~~Ken C Ruff~~	~~51402~~	1055		
020301A - ~~1~~ 1b - BH	S	Ken C Ruff	51302	1651		— ml H_2O 300ml KCl — ml HNO_4
	B	Ken C Ruff	51402	1055		
020301A - ~~1~~ 2a - BH	S	Ken C Ruff	51302	1649		— ml H_2O 300ml KCl — ml HNO_4
	B	Ken C Ruff	51402	1118		
020301A - 2b - BH	S	Ken C Ruff	51302	1649		
	B					

Were all seals intact?____Yes _____No (Describe seal and reasoning in the "Remarks")

Were all liquid levels at marked levels?______Yes _______No (Estimate loss in the "Remarks")

Received By Sample Custodian ________________ ________ ________

(Full Signature) (Date) (Time)

Remarks: 020301A-1-BH - 5% KMnO4 added @ 740 / Recovered @ 800
5% KMnO4 Batch @ 1600 5.8.02
Run 2 KCl impinges, KMnO4 added @ 1213, 1313
5/13/02 Run 3 KCl impingers, KMnO4 added @ 1217, PINK @ 12:22, CONT. 3 Pink @ 135

Job Number: 020301A

Done By / Date: TS / 5.9.02

Final Check By / Date: ______ / ______

Air Compliance Testing, Inc.

(Ontario Hydro.xls-BH Record of Custody) 3/8/2002

Ontario Hydro BH Record of Custody

ion Container Number:____________________

Seal I.D. no.		Full Signature	Date	Time	Reason for Breaking Seal	Final Vol. ml
020301A - 1 a BH	S	[illegible]	51402	1057		KR 7.5 ml H_2O 300ml KCl 100 ml HNO_3
	B					
020301A - 1 - BH	S					– ml H_2O 300ml KCl – ml HNO_3
	B					
	S					
	B					
020301A - 2 a - BH	S	[illegible]	51402	1120		KR 11.5 ml H_2O 300ml KCl 100 ml HNO_3
	B					
020301A - 2 - BH	S					– ml H_2O 300ml KCl – ml HNO_3
	B					
	S					
	B					
020301A - 3 a - BH	S	[illegible]	51402	1137		KR 9.7 ml H_2O 300ml KCl 120 ml HNO_3
	B					
020301A - 3 - BH	S					– ml H_2O 300ml KCl – ml HNO_4
	B					
	S					
	B					
020301A - 4 - BH	S					______ml H_2O 300ml KCl ______ml HNO_4
	B					
020301A - 4 - BH	S					______ml H_2O 300ml KCl ______ml HNO_4
	B					
	S					
	B					

Were all seals intact?____Yes _____No (Describe seal and reasoning in the "Remarks")

Were all liquid levels at marked levels?______Yes _______No (Estimate loss in the "Remarks")

Received By Sample Custodian ____________________ __________ __________

(Full Signature) (Date) (Time)

Remarks: ____

____

Job Number: 020301A

Done By / Date: KR / 5/14/02

Final Check By / Date: ______ / ______

Ontario Hydro IM4567 Record of Custody

tion Container Number: 001

Seal I.D. no.		Full Signature	Date	Time	Reason for Breaking Seal	Final Vol. ml
020301A - 1 - IM4	S	Tate Strickl	5-9-02	859		~~7.30.1~~ 7.3 mlH_2O 100ml HNO_3-H_2O_2 100ml HNO_3
	B					
020301A - 2 - IM4	S	Tate Strickl	5-10-02	1316		11.5 mlH_2O 100ml HNO_3-H_2O_2 100ml HNO_3
	B					
020301A - 3 - IM4	S	[illegible]	5-13-02	1410	9.1	(R) ~~213.9~~ mlH_2O total ~~100ml HNO_3-H_2O_2~~ ~~100ml~~ HNO_3
	B					
020301A - 4 - IM4	S					______ mlH_2O 100ml HNO_3-H_2O_2 100ml HNO_3
	B					
	S					
	B					
020301A - 1 - IM567	S	TS	5-9-02	0900		0.1 ml H_2O 300ml $KMnO_4$ 150 ml HNO_3
	B					
020301A - 2 - IM567	S	Tate Strickl	5-10-02	1316		3.5 ml H_2O 300ml $KMnO_4$ 150 ml HNO_3
	B					
020301A - 3 - IM567	S	[illegible]	5-13-02	1600		2.6 ml H_2O 300ml $KMnO_4$ 150 ml HNO_3
	B					
020301A - 4 - IM567	S					______ ml H_2O 300ml $KMnO_4$ ______ ml HNO_3
	B					
	S					
	B					
	S					
	B					

Were all seals intact?____Yes _____No (Describe seal and reasoning in the "Remarks")

Were all liquid levels at marked levels?______Yes _______No (Estimate loss in the "Remarks")

Received By Sample Custodian ____________________ __________ __________

(Full Signature) (Date) (Time)

Remarks: $KMnO_4$ Reagent Batch @ 1536 5-8-02 / 5% HNO_3 - 10% H_2O_2 Reagent batch @ 1552 5-8-02 Run 1 recovered @ 820, Color check @ 10

$KMnO_4$ Reagent Batch @ 1030 5-9-02

Job Number: 020301A

Done By / Date: TS / 5-9-02

Final Check By / Date: ______ / ______

Ontario Hydro Record of Custody Blanks

ion Container Number: 001

Seal I.D. no.		Full Signature	Date	Time	Reason for Breaking Seal	Final Vol. ml	Filter Number
020301A - BL - 7	S	[illegible]	5-9-02	1702		50ml 0.1N HNO_3	
	B						
020301A - BL - 8	S	[illegible]	5-8-02	1707		50ml KCl	
	B						
020301A - BL - 9	S	[illegible]	5-8-02	1700		50ml HNO_3 -H_2O_2	
	B						
020301A - BL - 10	S	[illegible]	5-8-02	1652		50ml $KMnO_4$	
	B						
020301A - BL - 11	S	[illegible]	5-8-02	1710		100ml 10% Hydroxyl amine	
	B						
020301A - BL - 12	S	[illegible]	5-14-02	918			3 Quartz Filters
	B						
020301A-BL-10a	S	[illegible]	5-9-02	1413		50ml $KMnO_4$	
	B						
020301A-BL-10b	S	[illegible]	5-9-02	2225		50ml $KMnO_4$	
	B						
	S						
	B						
	S						
	B						
	S						
	B						
	S						
	B						
	S						
	B						

Were all seals intact?____Yes _____No (Describe seal and reasoning in the "Remarks")

Were all liquid levels at marked levels?______Yes _______No (Estimate loss in the "Remarks")

Received By Sample Custodian ____________ ________ ________

(Full Signature) (Date) (Time)

Remarks: ______________________________

Job Number: 020301A

Done By / Date: TS / 5-9-02

Final Check By / Date ______ / ______

Ontario Hydro Filter Record of Custody

ion Container Number: ____________________

Seal I.D. no.		Full Signature	Date	Time	Reason for Breaking Seal	Final Vol. ml	Filter Number
020301B - 1 - F	S	TSI K. R. C.	5 2 02	1513	Filter FH Rinse Recovery		
	B	K. R. C.	5 14 02	923			
020301B - 1 - F	S	K. R. C.	5 14 02	957			
	B						
	S						
	B						
020301B - 2 - F	S	TSI K. R. C.	5 2 02	1517	Filter FH Rinse Recovery		
	B	K. R. C.	5 14 02	1015			
020301B - 2 - F	S	K. R. C.	5 14 02	1021			
	B						
	S						
	B						
020301B - 3 - F	S	TSI K. R. C.	5 2 02	1521	Filter Recovery FH Rinse		
	B	K. R. C.	5 14 02	1028			
020301B - 3 - F	S	K. R. C.	5 14 02	1034			
	B						
	S						
	B						
020301B - 4 - F	S						
	B						
020301B - 4 - F	S						
	B						
	S						
	B						

Were all seals intact?____Yes _____No (Describe seal and reasoning in the "Remarks")

Were all liquid levels at marked levels?______Yes _______No (Estimate loss in the "Remarks")

Received By Sample Custodian ____________________ ____________ ____________

(Full Signature) (Date) (Time)

Remarks: ____

____

Air Compliance Testing, Inc.
(Ontario Hydro.xls-Filter Record of Custody) 3/8/2002

Job Number: 020301B
Done By / Date: KR / 5 14 02
Final Check By / Date: ______ / ______

Ontario Hydro FH Record of Custody

ation Container Number: 001

Seal I.D no		Full Signature	Date	Time	Reason for Breaking Seal	Final Vol. ml
020301B - 1 - FH	S	[signature]	5-9-02	1300		100 ml 0.1N HNO_3
	B	[signature]	5 14 02	932		
020301B - 1 - FH	S	[signature]	5 14 02	956		+10 ml 0.1N HNO_3
	B					
	S					
	B					
020301B - 2 - FH	S	[signature]	5-9-02	1732		100 ml HNO_3
	B	[signature]	5 14 02	1013		
020301B - 2 - FH	S	[signature]	5 14 02	1018		+20 ml HNO_3
	B					
	S					
	B					
020301B - 3 - FH	S	[signature]	5-10-02	858		100 ml HNO_3
	B	[signature]	5 14 02	1027		
020301B - 3 - FH	S	[signature]	5 14 02	1031		+20 ml HNO_3
	B					
	S					
	B					
020301B - 4 - FH	S					____ ml HNO_3
	B					
020301B - 4 - FH	S					____ ml HNO_3
	B					
	S					
	B					

Were all seals intact?____Yes ____No (Describe seal and reasoning in the "Remarks")

Were all liquid levels at marked levels?____Yes ____No (Estimate loss in the "Remarks")

Received By Sample Custodian ________ (Full Signature) ________ (Date) ________ (Time)

Remarks: ________________

Job Number: 020301B

Done By / Date: TS / 5-9-02

Final Check By / Date: ____ / ____

Ontario Hydro BH Record of Custody

ion Container Number: 001 / 002

Seal I.D. no.		Full Signature	Date	Time	Reason for Breaking Seal	~~Final~~ Vol. ml
020301B - 1a - BH	S	[signature]	5-9-02	1301	addition of 5% $KMnO_4$ @ 1438	204.7 ml H_2O 300ml KCl 150 ml HNO_3
	B	[signature]	5-13-02	1433		
020301B - 1b - BH	S	[signature]	5-9-02	1301	addition of 5% $KMnO_4$ @ 1433	— ml H_2O 300ml KCl 150 ml HNO_3
	B	[signature]	5-13-02	1433		
020301B-1A-BH	S	[signature]	5-13-02	1653	Filter BH Rinse	10ml .1N HNO_3
	B	[signature]	5-14-02	1008		
020301B - 2 - BH	S	[signature]	5-9-02	2009	addition of 5% $KMnO_4$ @ 1438	270.3 ml H_2O 300ml KCl 150 ml HNO_3
	B	[signature]	5-13-02	1433		
020301B - 2a - BH	S	[signature]	5-9-02	2009	addition of 5% $KMnO_4$ @ 1439	~~276.2~~ ml H_2O 300ml KCl 150 ml HNO_3
	B	[signature]	5-13-02	1433		
020301B-1b-BH	S	[signature]	5-13-02	1653		
	B					
020301B - 3 - BH	S	[signature]	5-10-02	1001	addition of 5% $KMnO_4$ @ 1439	276.2 ml H_2O 300ml KCl 150 ml HNO_3
	B	[signature]	5-13-02	1434		
020301B - 3a - BH	S	[signature]	5-10-02	1001	addition of 5% $KMnO_4$ @ 1439	— ml H_2O 300ml KCl 150 ml HNO_4
	B	[signature]	5-13-02	1434		
020301B-2a-BH	S	[signature]	5-13-02	1654	Filter BH Rinse	
	B	[signature]	5-14-02	1013		
020301B - ~~4~~ 2b - BH	S	[signature]	5-13-02	1654		— ml H_2O 300ml KCl — ml HNO_4
	B					
020301B - ~~4~~ 3a - BH	S	[signature]	5-13-02	1655		ml H_2O 300ml KCl ml HNO_4
	B	~~[signature]~~	~~5-14-02~~	~~1027~~		
020301B-3b-BH	S	[signature]	5-13-02	1655	Filter BH Rinse	
	B	[signature]	5-14-02	1027		

Were all seals intact?____Yes _____No (Describe seal and reasoning in the "Remarks")

Were all liquid levels at marked levels?______Yes _______No (Estimate loss in the "Remarks")

Received By Sample Custodian ____________ ________ ________

(Full Signature) (Date) (Time)

Remarks: Run-1 5% $KMnO_4$ added @ 1152 and 1207, 1254
Run-2 5% $KMnO_4$ added @ 1642 and 1722, 1856
Run-3 5% $KMnO_4$ added @ 739 and 810

Job Number: 020301B
Done By / Date: TS / 5-9-02
Final Check By / Date: ______ / ______

Ontario Hydro BH Record of Custody

ion Container Number:________________

Seal I.D. no.		Full Signature	Date	Time	Reason for Breaking Seal	Final Vol. ml
020301B - 1 - BH a	S	K...	5 14 02	1011		– ml H_2O 300ml KCl +10 ml HNO_3
	B					
020301B - 1 - BH	S					– ml H_2O 300ml KCl – ml HNO_3
	B					
	S					
	B					
020301B - 2 - BH a	S	K...	5 14 02	1023		– ml H_2O 300ml KCl +10 ml HNO_3
	B					
020301B - 2 - BH	S					– ml H_2O 300ml KCl – ml HNO_3
	B					
	S					
	B					
020301B - 3 - BH a	S	K...	5 14 02	1038		– ml H_2O 300ml KCl +10 ml HNO_3
	B					
020301B - 3 - BH	S					– ml H_2O 300ml KCl – ml HNO_4
	B					
	S					
	B					
020301B - 4 - BH	S					____ml H_2O 300ml KCl ____ml HNO_4
	B					
020301B - 4 - BH	S					____ml H_2O 300ml KCl ____ml HNO_4
	B					
	S					
	B					

Were all seals intact?____Yes _____No (Describe seal and reasoning in the "Remarks")

Were all liquid levels at marked levels?______Yes _______No (Estimate loss in the "Remarks")

Received By Sample Custodian ________________ ________ ________

(Full Signature) (Date) (Time)

Remarks: ____

Job Number: 020301B

Air Compliance Testing, Inc.

(Ontario Hydro.xls-BH Record of Custody) 5/14/02

Done By / Date: KR / 5-14-02

Final Check By / Date: ______ / ______

Ontario Hydro IM4567 Record of Custody

tion Container Number: 001

Seal I.D. no.		Full Signature	Date	Time	Reason for Breaking Seal	Final Vol. ml
020301B - 1 - IM4	S	Tate Strafft	5-9-02	1300		2.9 mlH$_2$O 100ml HNO$_3$-H$_2$O$_2$ 100ml HNO$_3$
	B					
020301B - 2 - IM4	S	Tate Strafft	5-9-02	1733		3.3 mlH$_2$O 100ml HNO$_3$-H$_2$O$_2$ 100ml HNO$_3$
	B					
020301B - 3 - IM4	S	Tate Straft	5-10-02	859		2.2 mlH$_2$O 100ml HNO$_3$-H$_2$O$_2$ 100ml HNO$_3$
	B					
020301B - 4 - IM4	S					— mlH$_2$O 100ml HNO$_3$-H$_2$O$_2$ 100ml HNO$_3$
	B					
	S					
	B					
020301B - 1 - IM567	S	Tate Strafft	5-9-02	1302		3.1 ml H$_2$O 300ml KMnO$_4$ 150 ml HNO$_3$
	B					
020301B - 2 - IM567	S	Tate Strafft	5-9-02	1734		1.4 ml H$_2$O 300ml KMnO$_4$ 150 ml HNO$_3$
	B				TS	
020301B - 3 - IM567	S	Tate Strafft	5-10-02	~~1000~~ 900		2.5 ml H$_2$O 300ml KMnO$_4$ 150 ml HNO$_3$
	B					
020301B - 4 - IM567	S					— ml H$_2$O 300ml KMnO$_4$ — ml HNO$_3$
	B					
	S					
	B					
	S					
	B					

Were all seals intact?____Yes _____No (Describe seal and reasoning in the "Remarks")

Were all liquid levels at marked levels?______Yes _______No (Estimate loss in the "Remarks")

Received By Sample Custodian ________________ ________ ________

(Full Signature) (Date) (Time)

Remarks: KMnO$_4$ Reagent Batch @ 2008 5-9-02

Job Number: 020301B

Done By / Date: TS / 5-9-02

Final Check By / Date ______ / ______

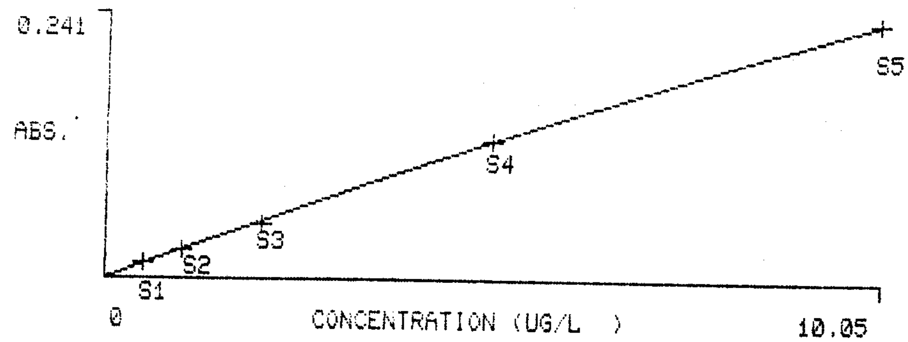
205/06 - Hg


```
HG                        AA-BG    BG
MAIN:  -0.001          PA-0.018  0.130
                       PH-0.001  0.012

  0.000     AUTOZERO

HG                        AA-BG    BG
MAIN:   0.014          PA 0.281 -0.101
                       PH 0.014 -0.007

  0.50      1.STANDARD

HG                       AA-BG    BG
MAIN:    0.93 UG/L  PA 0.461 -0.094
                    PH 0.027 -0.007

E61 Sample concentration greater than highest standard

  0.98      2.STANDARD

HG                       AA-BG    BG
MAIN:    1.90 UG/L  PA 0.927 -0.073
                    PH 0.052 -0.007

E61 Sample concentration greater than highest standard

  1.97      3.STANDARD

HG                       AA-BG    BG
MAIN:    4.97 UG/L  PA 2.316 -0.059
                    PH 0.130 -0.007

E61 Sample concentration greater than highest standard

  4.99      4.STANDARD

HG                       AA-BG    BG
MAIN:    9.27 UG/L  PA 4.151 -0.020
                    PH 0.241 -0.005

E61 Sample concentration greater than highest standard

  9.81      5.STANDARD
```

HGA DISPLAY CALIBRATION MODE
ELEMENT: HG - PEAK HEIGHT

PRINTER: ON
BG CORR: ON
UNITS : UG/L
CH.MASS:

9.81



PEAK AREA (A-S)
AA-BG: 4.151
BG: -0.020

PEAK HEIGHT (A)
AA-BG: 0.241
BG: -0.005

20 ml

Sample	HG MAIN	PA AA-BG	PA BG	PH AA-BG	PH BG
ICV	4.79 UG/L	2.115	-0.028	0.124	-0.004
ICB	0.00 UG/L	-0.016	-0.199	0.000	-0.012
B-12	0.07 UG/L	0.008	-0.127	0.002	-0.010
	0.07 UG/L	0.028	-0.090	0.002	-0.008
A1-1	1.72 UG/L	0.890	-0.098	0.046	-0.009
A1-1	1.72 UG/L	0.894	-0.132	0.046	-0.012
A1-1	1.75 UG/L	0.840	-0.088	0.047	-0.008
A2-1	2.62 UG/L	1.361	-0.109	0.070	-0.009
A2-1	2.68 UG/L	1.357	-0.087	0.072	-0.009
A3-1	0.88 UG/L	0.398	-0.051	0.024	-0.007
A3-1	0.85 UG/L	0.415	0.013	0.023	-0.001
B1-1	-0.04 UG/L	-0.010	-0.142	-0.001	-0.012
B1-1	-0.04 UG/L	0.003	-0.134	-0.001	-0.011
B2-1	0.03 UG/L	0.010	-0.119	0.001	-0.010
B2-1	0.09 UG/L	0.028	-0.12[illegible]	0.002	[illegible]
B3-1	0.04 UG/L	0.025	-0.136	0.001	-0.011
B3-1		0.047	-0.114	0.002	-0.010
CCV	4.91 UG/L	2.170	-0.027	0.127	-0.003
CCB	0.0[illegible] UG/L	0.025	-0.006	0.001	-0.002
B-7	0.04 UG/L	-0.003	-0.097	0.001	-0.009

20ml

Sample	Element	MAIN	PA AA-BG	PA BG	PH AA-BG	PH BG
B-7	HG	0.00 UG/L	0.017	-0.089	0.000	-0.010
A1-2	HG	0.70 UG/L	0.346	-0.064	0.019	-0.009
A1-2	HG	0.63 UG/L	0.312	-0.080	0.017	-0.009
A2-2	HG	1.20 UG/L	0.593	-0.056	0.033	-0.007
A2-2	HG	1.22 UG/L	0.604	-0.041	0.033	-0.007
A3-2	HG	0.38 UG/L	0.214	-0.072	0.010	-0.007
A3-2	HG	0.41 UG/L	0.239	-0.122	0.011	-0.011
B1-2	HG	0.03 UG/L	-0.010	-0.080	0.001	-0.010
B1-2	HG	0.01 UG/L	0.015	-0.089	0.000	-0.008
B2-2	HG	-0.01 UG/L	-0.002	-0.051	-0.000	-0.007
B2-2	HG	0.06 UG/L	0.040	-0.092	0.002	-0.007
B3-2	HG	0.01 UG/L	0.016	-0.078	0.000	-0.008
B3-2	HG	0.06 UG/L	0.017	-0.108	0.002	-0.010
CCV	HG	5.05 UG/L	2.212	-0.101	0.130	-0.003
CCB	HG	0.10 UG/L	0.048	0.042	0.003	0.000
B-8	HG	0.00 UG/L	0.017	-0.090	0.000	-0.008
B-8	HG	0.03 UG/L	0.013	-0.126	0.001	-0.010
A1-3	HG	3.22 UG/L	1.526	-0.046	0.085	-0.004
A1-3	HG	3.24 UG/L	1.488	-0.056	0.086	-0.005
A2-3	HG	5.10 UG/L	2.343	-0.074	0.131	-0.006
A2-3	HG	5.21 UG/L	2.185	-0.063	0.134	-0.006
A3-3	HG	4.98 UG/L	2.141	-0.075	0.128	-0.007
A3-3	HG	4.99 UG/L	2.174	-0.068	0.129	-0.008
A3-3	HG	5.08 UG/L	2.321	-0.048	0.131	-0.008
B1-3	HG	-0.01 UG/L	-0.012	-0.057	-0.000	-0.006
	HG	0.03 UG/L	0.022	-0.067	0.001	-0.006
B2-3	HG	-0.01 UG/L	0.012	-0.099	0.000	-0.010
	HG	0.01 UG/L	0.011	-0.110	0.000	-0.007
B3-3	HG	0.00 UG/L	0.018	-0.140	0.000	-0.010
	HG	0.03 UG/L	0.014	-0.150	0.001	-0.011

Note	Sample	HG MAIN	PA AA-BG	PA BG	PH AA-BG	PH BG
	CCV	4.84 UG/L	2.175	-0.036	0.125	-0.002
	CCB	0.06 UG/L	0.036	-0.170	0.002	-0.013
5 ml	B-9	0.07 UG/L	0.001	-0.079	0.002	-0.009
		0.01 UG/L	0.019	-0.057	0.000	-0.007
10 ml	A1-4	0.09 UG/L	0.062	-0.054	0.002	-0.003
		0.04 UG/L	0.041	-0.06[illegible]	0.001	-0.008
	A1-4S	4.98 UG/L	2.355	-0.077	0.128	-0.009
		5.01 UG/L	2.402	-0.019	0.129	-0.006
	A2-4	0.00 UG/L	-0.010	-0.092	0.000	-0.008
		0.01 UG/L	0.019	-0.035	0.000	-0.006
	A3-4	0.04 UG/L	0.032	-0.102	0.001	-0.01[illegible]
		[illegible] UG/L	-0.001	-0.112	-0.001	-0.011
	B1-4	[illegible] UG/L	0.032	-0.114	0.002	-0.010
	B1-4	0.04 UG/L	0.019	-0.091	0.001	-0.010
	B1-4	0.0[illegible] UG/L	0.027	-0.121	0.001	-0.011
	B2-4	0.04 UG/L	0.031	-0.076	0.001	-0.009
	B2-4	0.10 UG/L	0.035	-0.104	0.003	-0.010
	CCV	5.06 UG/L	2.287	-0.021	0.130	-0.003
	CCB	0.06 UG/L	0.005	-0.149	0.002	-0.011
	B3-4	0.03 UG/L	0.021	-0.090	0.001	-0.009
20 ml	B3-4	0.06 UG/L	0.038	-0.093	0.002	-0.009
	B-10	0.06 UG/L	0.005	-0.035	0.002	-0.005
	B-10	0.16 UG/L	0.055	-0.046	0.004	-0.007
	B-10a	0.01 UG/L	0.026	-0.065	0.000	-0.008
	B-10a	0.12 UG/L	0.033	-0.042	0.003	-0.006
	B-10b	0.06 UG/L	0.025	-0.084	0.002	-0.007
	B-10b	0.00 UG/L	[illegible]	[illegible]	[illegible]	[illegible]
	A1-5	0.23 UG/L	0.140	-0.097	0.006	-0.008
	A1-5	[illegible] UG/L	0.114	-0.102	0.006	-0.008
	A2-5	0.15 UG/L	0.089	-0.099	0.004	-0.008

Note	Sample	HG MAIN	PA AA-BG	PA BG	PH AA-BG	PH BG
20ml	A2-5	0.17 UG/L	0.096	-0.054	0.005	-0.004
	A3-5	0.36 UG/L	0.191	-0.019	0.010	-0.005
	A3-5	0.36 UG/L	0.166	-0.056	0.010	-0.006
	B1-5	0.57 UG/L	0.299	-0.099	0.016	-0.010
	CCV	4.94 UG/L	2.154	-0.018	0.128	0.000
	CCB	0.04 UG/L	0.003	-0.133	0.001	-0.012
	B1-5	0.58 UG/L	0.298	-0.042	0.016	-0.007
	B2-5	0.64 UG/L	0.336	-0.055	0.018	-0.007
	B2-5	0.63 UG/L	0.316	-0.003	0.017	-0.005
	B2-5	0.67 UG/L	0.324	0.015	0.018	-0.002
	B3-5	1.22 UG/L	0.618	-0.051	0.033	-0.007
		1.22 UG/L	0.561	-0.031	0.033	-0.005
10ml	B-11	0.04 UG/L	0.023	-0.300	0.001	-0.011
		0.03 UG/L	0.043	-0.261	0.001	-0.013
	CCV	4.83 UG/L	2.219	-0.038	0.125	-0.001
	CCB	0.03 UG/L	0.032	-0.133	0.001	-0.010

@

Del 5/15/02, 9:12AM Recd By #

FedEx Express USA Airbill

FedEx Tracking Number 8335 9372 0110

Sender's Copy

1 From Please print and press hard.

Date 5-14-02 Sender's FedEx Account Number 1805-5745-8

Sender's Name Kevin R. Roff Phone (440) 230-1100

Company AIR COMPLIANCE TESTING

Address 9438 AKINS RD

Dept./Floor/Suite/Room

City CLEVELAND State OH ZIP 44133

2 Your Internal Billing Reference 020301

First 24 characters will appear on invoice.

3 To

Recipient's Name William Wadlin Phone (919) 942-8607

Company First Analytical Laboratories

Address 1126 Burning Tree Dr.

To "HOLD" at FedEx location, print FedEx address. We cannot deliver to P.O. boxes or P.O. ZIP codes.

Address

Dept./Floor/Suite/Room

City Chapel Hill State NC ZIP 27514

5/15/02 av FedEx Ramus Chapel Hill NC 5:54 AM

By using this Airbill you agree to the service conditions on the back of this Airbill and in our current Service Guide, including terms that limit our liability.

Questions? Visit our Web site at fedex.com

or call 1-800-Go-FedEx 1-800-463-3339.

0214508648

4a Express Package Service — Packages up to 150 lbs.

- [x] FedEx Priority Overnight — Next business morning
- [ ] FedEx Standard Overnight — Next business afternoon
- [ ] FedEx First Overnight
- [ ] FedEx 2Day — Second business day
- [ ] FedEx Express Saver — Third business day

FedEx Envelope rate not available. Minimum charge: One-pound rate

4b Express Freight Service — Packages over 150 lbs. Delivery commitment may be later in some areas.

- [ ] FedEx 1Day Freight* — Next business day
- [ ] FedEx 2Day Freight — Second business day
- [ ] FedEx 3Day Freight — Third business day

* Call for Confirmation:

5 Packaging — * Declared value limit $500

- [ ] FedEx Envelope*
- [ ] FedEx Pak* — Includes FedEx Small Pak, FedEx Large Pak, and FedEx Sturdy Pak
- [x] Other

6 Special Handling — Include FedEx address in Section 3.

- [ ] SATURDAY Delivery — Available ONLY for FedEx Priority Overnight and FedEx 2Day to select ZIP codes
- [ ] HOLD Weekday at FedEx Location — NOT Available for FedEx First Overnight
- [ ] HOLD Saturday at FedEx Location — Available ONLY for FedEx Priority Overnight and FedEx 2Day to select locations

Does this shipment contain dangerous goods? One box must be checked.

- [ ] No
- [x] Yes — As per attached Shipper's Declaration
- [ ] Yes — Shipper's Declaration not required
- [ ] Dry Ice — Dry Ice, 9, UN 1845 ____ x ____
- [ ] Cargo Aircraft Only

Dangerous Goods (including Dry Ice) cannot be shipped in FedEx packaging.

7 Payment Bill to:

- [x] Sender — Acct. No. in Section 1 will be billed
- [ ] Recipient
- [ ] Third Party
- [ ] Credit Card
- [ ] Cash/Check

FedEx Acct. No. / Credit Card No. Exp. Date

Total Packages	Total Weight	Total Declared Value†
1	40 lbs	$ 10,000 .00

†Our liability is limited to $100 unless you declare a higher value. See back for details.

FedEx Use Only

8 Release Signature Sign to authorize delivery without obtaining signature.

By signing you authorize us to deliver this shipment without obtaining a signature and agree to indemnify and hold us harmless from any resulting claims.

447

Ontario Hydro Isokinetic Field Data

Plant	Powerspan	Meter box no.	T-...B- 010	Gamma	1.0096
Location	ECO Inlet Duct	Pump no.	T-PMP- 010	K Factor	~~4.2~~ 4.2 /
Run no.	1	Nomograph no.	T-NOM- ~~003~~ 002	Nozzle Size, in.	0.502
Test start time	1850	Probe no.	T-PRB- ~~408~~ SHC 407	Barometric pressure, in.Hg	29.25
Test stop time	2153 AN	Filter box no.	T-FLB- 001	Ambient temperature, °F	74
Pre-test leak rate @ 15in.Hg	~~X~~ SHC 0.002	Impinger box no.	T-IMB- 014	Filter box temperature setting, °F	248 ± 25
Post-test leak rate @ in.Hg	(see sheet 2)	Umbilical cord no.	T-UMC- 301	Probe temperature setting, °F	248 ± 2559
Pre-test pitot leak check - ✓ total ✓ static		Umbilical adapter no.	T-UMA- 005	Orsat flow rate setting, SCFH	0.22
Post-test pitot leak check - ✓ total ✓ static		Orsat bag no.	020301-1-OR	Meter box operator SHC	Date 05/08/02

POINT	CLOCK TIME min	DRY GAS METER CF	PITOT In. H_2O ΔP	ORIFICE ΔH In. H_2O DESIRED	ORIFICE ΔH In. H_2O ACTUAL	PROBE TEMP °F	STACK TEMP °F	DRY GAS TEMP, °F INLET	DRY GAS TEMP, °F OUTLET	FILTER TEMP °F	IMPINGER TEMP °F	PUMP VACUUM in.Hg	ORSAT FLOW SCFH	STATIC PRESSURE ± in.H_2O
1	0	~~197.374~~	0.01	0.42	0.42	247	260	75	72	234	48	3.0	0.2	-16.4
1	5	199.37	0.01	0.42	0.42	234	274	77	73	236	48	2.9	0.2	–
1	10	201.15	0.012	0.43	0.43	238	275	78	74	237	48	3.0	0.2	–
2	15	203.00	0.012	0.43	0.43	248	276	79	74	240	48	3.0	0.2	–
2	20	204.85	0.012	0.43	0.43	273	276	80	74	234	48	3.2	0.2	–
2	25	206.79	0.012	0.43	0.43	235	276	81	75	235	48	3.5	0.2	–
3	30	208.52	0.012	0.43	0.43	231	274	81	75	241	48	3.9	0.2	–
3	35	210.37	0.012	0.43	0.43	244	274	81	75	243	49	3.7	0.2	–
3	40	212.19	0.010	0.42	0.42	252	274	82	76	251	49	4.0	0.2	–
4	45	214.03	0.010	0.42	0.42	261	264	82	76	252	50	4.0	0.2	–
4	50	215.54	0.005	0.21	0.21	234	253	81	76	254	52	3.4	0.2	–
4	55.33	217.12	0.008	0.319	0.33	230	241	80	76	239	55	3.9	0.2	–
1	60	218.601	0.010	0.42	0.42	230	241	81	76	240	54	4.0	0.2	–
1	65	220.40	0.005	0.21	0.21	~~274~~ 140	140	81	76	239	55	3.5	0.2	–
1	70	221.89	0.005	0.21	0.21	257	145	81	76	239	55	3.5	0.2	–
2	75	223.09	0.008	0.329	0.33	245	147	81	76	240	55	4.0	0.2	–
2	80	224.73	0.017	0.71	0.71	230	268	82	76	239	52	5.9	0.2	–
2	85	227.05	0.01	0.42	0.42	271	270	83	76	239	53	5.0	0.2	–
3	90	228.75	0.01	0.42	0.42	261	272	82	76	238	54	5.0	0.2	–
3	95	230.59	0.01	0.42	0.42	239	273	82	76	239	55	5.0	0.2	–
3	100	232.40	0.01	0.42	0.42	300	273	82	76	242	55	5.1	0.2	–
4	105	234.20	0.09	0.379	0.39	242	273	82	76	242	56	5.2	0.2	–
4	110	236.10	0.01	0.42	0.42	255	273	82	76	244	56	5.9	0.2	–
4	115	237.75	0.01	0.42	0.42	301	273	82	76	244	56	6.0	0.2	–
	120	239.649	~~0.01~~	~~0.42~~	~~0.42~~									
Final														

Port 1

Port 2

Nomograph Calibration Variables ΔH@ 1.744 Cp 0.84 Ts Tm Ps Pm ΔP Bws

Comments: 215.848 PAUSE AT ~~51.15~~ ~~19.43~~ 19:41 RESTART 19:45 51 MIN INTO THE RUN
PORT CHANGE TO #2 @ 19:56
PORT CHANGE TO #3 @ 20:55

Test Observers -

~~215~~ SHC

Air Compliance Testing, Inc.
(Ontario Hydro xls-Isokinetic Field Data) 3/8/2002

Job Number: 020301
Done By / Date: SHC / 050802
Final Check By / Date: A.N. / 5-31-02

Ontario Hydro Isokinetic Field Data (4)

Plant	Powerspan	Meter box no.	T-....B- 010	Gamma	1.0096
Location	ECO Inlet Duct	Pump no.	T-PMP- 010	K Factor	42 / /
Run no.	1 (PORT #3)	Nomograph no.	T-NOM- 002	Nozzle Size, in.	0.500
Test start time	20.58 (PORT #3)	Probe no.	T-PRB- 407	Barometric pressure, in.Hg	29.25
Test stop time	21.53	Filter box no.	T-FLB- 001	Ambient temperature, °F	74
Pre-test leak rate @ 15in.Hg	PORT #3 (SEE ...)	Impinger box no.	T-IMB- 014	Filter box temperature setting, °F	248 ± 25
Post-test leak rate @ 8 in.Hg	0.001	Umbilical cord no.	T-UMC- 301	Probe temperature setting, °F	248 ± 59
Pre-test pitot leak check - ✓ total	✓ static	Umbilical adapter no.	T-UMA- 005	Orsat flow rate setting, SCFH	0.222
Post-test pitot leak check - ✓ total	✓ static	Orsat bag no.	020301-1-OR	Meter box operator	SHC Date 050801

BOT ~~PORT~~ PORT #3

POINT	CLOCK TIME min	DRY GAS METER CF	PITOT In. H_2O ΔP	ORIFICE ΔH In. H_2O DESIRED	ORIFICE ΔH In. H_2O ACTUAL	PROBE TEMP °F	STACK TEMP °F	DRY GAS TEMP, °F INLET	DRY GAS TEMP, °F OUTLET	FILTER TEMP °F	IMPINGER TEMP °F	PUMP VACUUM in.Hg	ORSAT FLOW SCFH	STATIC PRESSURE ± in.H_2O
1	~~115~~ 120	239.649	0.01	0.42	0.42	253	257	80	76	215	54	6.5	2.2	—
1	~~130~~ 125	241.50	0.01	0.42	0.42	~~344~~	262	81	76	245	54	6.5	2.2	—
1	~~135~~ 130	243.32	0.01	0.42	0.42	314	266	81	76	245	54	6.9	2.2	—
2	~~140~~ 135	245.10	0.006	0.25	0.25	279	266	81	76	244	55	5.9	2.2	—
2	~~145~~ 140	246.61	0.007	0.29	0.29	284	266	80	75	244	55	6.1	2.2	—
2	~~150~~ 145	248.15	0.008	0.339	0.34	302	267	81	75	245	55	6.9	2.2	—
3	~~155~~ 150	249.67	0.009	0.379	0.38	264	268	81	75	240	55	7.2	2.2	—
3	~~160~~ 155	251.38	0.008	0.339	0.34	301	268	81	76	241	55	7.2	2.2	—
3	160	253.06	0.007	0.29	0.29	314	268	81	75	240	55	7.3	2.2	—
4	165	254.63	0.005	0.21	0.21	300	252	80	75	239	57	6.3	2.2	—
4	170 ~~175~~	255.98	0.005	0.21	0.21	297	247	80	75	238	57	6.3	0	—
4	175 ~~180~~	257.30	0.005	0.21	0.21	300	246	80	75	238	58	6.2	0	—
1 4														
4														
4														
2														
2														
2														
Final	160	258.750												

SHC

Nomograph Calibration Variables ΔH@ 1.744 Cp 0.84 Ts Tm Ps Pm ΔP Bws

Comments: PROBE TEMP AT ~~#~~ 125 MIN 248°F

Test Observers -

0.033
0.03

Job Number: 020301

Done By / Date: SHC / 050801

Final Check By / Date: A.N. / 5-31-02

Air Compliance Testing, Inc.

(Ontario Hydro.xls-Isokinetic Field Data (4)) 3/8/2002

239.649

Ontario Hydro Isokinetic Field Data (2)

1/2

Plant	Powerspan	Meter box no.	T-MB- 008	Gamma	1.0112
Location	ECO Inlet Duct	Pump no.	T-PMP- 008	K Factor	46 / /
Run no.	2	Nomograph no.	T-NOM- 002	Nozzle Size, in.	.502
Test start time	750	Probe no.	T-PRB- 407	Barometric pressure, in.Hg	29.52
Test stop time	~~11:0~~ 11:57 AM	Filter box no.	T-FLB- 006	Ambient temperature, °F	51
Pre-test leak rate @ 15in.Hg	0.002 ✓	Impinger box no.	T-IMB- 009	Filter box temperature setting, °F	248 ± 25
Post-test leak rate @ in.Hg	→ ?	Umbilical cord no.	T-UMC- 304	Probe temperature setting, °F	248 ± 25
Pre-test pitot leak check - ✓total ✓ static		Umbilical adapter no.	T-UMA- 003	Orsat flow rate setting, SCFH	0.2
Post-test pitot leak check - total static		Orsat bag no.	020301A-2-0R	Meter box operator	SHC Date 051002

	POINT	CLOCK TIME min	DRY GAS METER CF	PITOT In. H_2O ΔP	ORIFICE ΔH In. H_2O DESIRED	ORIFICE ΔH In. H_2O ACTUAL	PROBE TEMP °F	STACK TEMP °F	DRY GAS TEMP, °F INLET	DRY GAS TEMP, °F OUTLET	FILTER TEMP °F	IMPINGER TEMP °F	PUMP VACUUM in.Hg	ORSAT FLOW SCFH	STATIC PRESSURE ± in.H_2O
	1	0	284.919	0.011	0.55	0.55	263	255	—	58	257	52	3.5	0.2	-15.2
TOP PORT 1	1	5	286.96	0.013	0.60	0.60	263	264	—	58	257	52	3.6	0.2	—
	1	10	288.88	0.013	0.60	0.60	265	264	—	58	257	51	3.7	0.2	—
	1	15	290.94	0.013	0.60	0.60	265	264	—	~~49~~ 60	257	49	4.2	0.2	—
	2	20	293.01	0.014	0.649	0.65	263	264	—	61	258	49	4.2	0.2	—
	2	25	295.16	0.014	0.649	0.65	265	263	—	62	257	50 ~~47~~	4.5	0.2	—
	2	30	297.36	0.014	0.649	0.65	264	263	—	63	258	52	5.0	0.2	—
	2	35	299.59	0.014	0.649	0.65	267	263	—	64	259	51	5.2	0.2	—
	3	40	301.65	0.011	0.55	0.55	267	262	—	64	257	53 6	4.9	0.2	—
	3	45	303.63	0.010	0.46	0.46	264	261	—	65	256	54	4.9	0.05	—
✓	3	50	305.50	0.010	0.46	0.46	263	260	—	66	258	54	5.2	.1	—
	3	55	307.35	0.010	0.46	0.46	269	260	—	67	259	56	5.4	.15	—
	4	60	309.20	0.010	0.46	0.46	267	218	—	67	258	55	5.6	0.2	—
	4	65	311.05	0.010	0.46	0.46	265	167	—	68	259	54	5.7	0.2	—
	4	70	312.91	0.010	0.46	0.46	263	160	—	69	258	53	5.9	0.2	—
—	4	75	314.73	0.010	0.46	0.46	263	160	—	69	258	52	6.1	0.2	—
	1	80	316.97	0.010	0.46	0.46	267	126	—	70	258	52	6.1	0.2	—
PORT 2	1	85	318.21	0.010	0.46	0.46	266	204	—	70	258	52	6.2	0.2	—
	1	90	320.19	0.010	0.46	0.46	266	215	—	70	258	53	6.3	0.2	—
	1	95	322.02	0.010	0.46	0.46	267	213	—	71	258	51	6.3	0.2	—
	2	100	324.03	0.015	0.695	0.7	265	240	—	71	258	51	8.3	0.2	—
	2	105	326.31	0.016	0.74	0.74	266	259	—	72	258	52	9.1	0.2	—
	2	110	328.59	0.015	0.695 ~~0.695~~	0.7	267	255	—	72	261	50	9.1	0.2	—
	2	115	331.08	0.010	0.46	0.46	265 ~~259~~	259	—	72	258	54	9.3	0.2	—
	—	—													
	Final	/	NEXT PAGE												

Nomograph Calibration Variables ΔH@ 1.8407 Cp 0.84 Ts Tm Ps Pm ΔP Bws

Comments: PORTS OPENED AT 7:31 PORT CHANGES: START #2 9:10 START #3 START #4
RESUME #2 9:13 RESUME #3 RESUME #4

Test Observers - 0.086 0.064 0.002 | 284.919 |

Job Number: 020301A
Done By / Date: SHC / 051002
Final Check By / Date: A.W. / 5-31-02

Air Compliance Testing, Inc.
(Ontario Hydro.xls-Isokinetic Field Data (2)) 3/8/2002

Ontario Hydro Isokinetic Field Data (3)

Plant	Powerspan	Meter box no.	T-MFB- 008	Gamma	1.0112
Location	ECO Inlet Duct	Pump no.	T-PMP- 008	K Factor	46 / /
Run no.	2	Nomograph no.	T-NOM- 002	Nozzle Size, in.	0.502
Test start time	750 (PORT 1)	Probe no.	T-PRB- 407	Barometric pressure, in.Hg	29.52
Test stop time	~~4:55~~ 11:57	Filter box no.	T-FLB- 006	Ambient temperature, °F	51
Pre-test leak rate @ 15in.Hg	0.002	Impinger box no.	T-IMB- 009	Filter box temperature setting, °F	248 ~~±25~~ +25
Post-test leak rate @ 10 in.Hg	Ø	Umbilical cord no.	T-UMC- 304	Probe temperature setting, °F	248 ~~±25~~ +59
Pre-test pitot leak check - ✓ total ✓ static		Umbilical adapter no.	T-UMA- 003	Orsat flow rate setting, SCFH	0.2
Post-test pitot leak check - ✓ total ✓ static		Orsat bag no.	020301-A-2-OR	Meter box operator	SHC Date 051002

	POINT	CLOCK TIME min	DRY GAS METER CF	PITOT In. H_2O ΔP	ORIFICE ΔH In. H_2O DESIRED	ORIFICE ΔH In. H_2O ACTUAL	PROBE TEMP °F	STACK TEMP °F	DRY GAS TEMP, °F INLET	DRY GAS TEMP, °F OUTLET	FILTER TEMP °F	IMPINGER TEMP °F	PUMP VACUUM in.Hg	ORSAT FLOW SCFH	STATIC PRESSURE ± in.H_2O
PORT 2 (CONT'D)	3	120	333.02	0.01	0.46	0.46	267	260	—	73	258	53	8.1	0.2	—
	3	125	334.94	0.01	0.46	0.46	267	268	—	73	258	53	8.1	0.2	—
IN	3	130	336.79	0.01	0.46	0.46	268	263	—	73	258	54	8.3	0.2	—
	3	135	338.65	0.01	0.46	0.46	267	263	—	73	258	54	8.4	0.2	—
	4	140	340.50	0.01	0.46	0.46	267	263	—	73	258	55	8.4	0.2	—
	4	145	342.41	0.010	0.46	0.46	267	263	—	73	258	54	8.4	0.2	—
	4	150	344.27	0.011	0.505	0.50	264	263	—	73	258	52	8.7	0.2	—
	4	155	346.20	0.01	0.46	0.46	265	263	—	73	258	55	8.9	0.2	—
PORT 3 BOT	1	160	348.05	0.01	0.46	0.46	267	236	—	73	258	51	8.9	0.2	—
	1	165	350.60	0.01	0.46	0.46	265	257	—	73	258	51	9.1	0.2	—
	1	170	352.46	0.01	0.46	0.46	267	258	—	73	258	52	9.2	0.2	—
	1	175	354.28	0.01	0.46	0.46	268	259	—	73	258	51	9.2	0.2	—
	2	180	356.12	0.01	0.46	0.46	265	257	—	72	258	51	9.6	0.2	—
	2	185	~~358~~ 357.97	0.01	0.46	0.46	265	257	—	72	258	51	9.7	0.2	—
	2	190	359.83	0.007	0.32	0.32	265	257	—	72	258	53	9.0	.05	-11.4
	2	195	361.50	0.007	0.32	0.32	268	257	—	72	258	53	8.8	.00	—
	3	200	363.05	0.007	0.32	0.32	265	255	—	72	258	53	9.3	~~.01~~	—
	3	205	364.60	0.007	0.32	0.32	267	253	—	73	258	53	9.7	.01	—
	3	210	366.17	0.007	0.32	0.32	267	253	—	73	258	53	9.8	.01	—
	3	215	367.75	0.007	0.32	0.32	263	252	—	73	258	53	9.8	.01	—
	4	220	369.34	0.007	0.32	0.32	266	220	—	73	258	53	9.3	0.1	—
	4	225	370.87	0.007	0.32	0.32	266	191	—	73	258	54	9.9	0.2	—
	4	230	372.44	0.006	0.28	0.28	262	187	—	73	258	54	9.7	0.1	—
	4	235	373.95	0.006	0.28	0.28	266	187	—	73	258	57	9.9	0	-16.8
	Final	240	375.43												

Nomograph Calibration Variables ΔH@ 1.8407 Cp 0.84 Ts Tm Ps Pm ΔP Bws

Comments: #2 PORT CHANGE @ 10:32, #3 PORT @ 10:35

Test Observers -

Job Number: ~~030107A~~ 020301A

Done By / Date: SHC / 051002

Final Check By / Date: A.N / 5-31-02

Air Compliance Testing, Inc.

(Ontario Hydro.xls Isokinetic Field Data (3)) 3/8/2002

Ontario Hydro Isokinetic Field Data

Plant	Powerspan
Location	ECO ~~Exhaust Duct~~ Inlet
Run no.	3
Test start time	12:24
Test stop time	16:28 PM
Pre-test leak rate @ 15in.Hg	0.000
Post-test leak rate @	~~in.Hg~~
Pre-test pitot leak check -	☑ total ☑ static
Post-test pitot leak check -	☐ total ☐ static

Meter box no.	T-MTB-	008
Pump no.	T-PMP-	008
Nomograph no.	T-NOM-	002
Probe no.	T-PRB-	606
Filter box no.	T-FLB-	011
Impinger box no.	T-IMB-	014
Umbilical cord no.	T-UMC-	601
Umbilical adapter no.	T-UMA-	001
Orsat bag no.		020301A-3-OR

Gamma	1.0112
K Factor	46 / /
Nozzle Size, in.	0.503
Barometric pressure, in.Hg	29.58
Ambient temperature, °F	~~60~~ 62
Filter box temperature setting, °F	248 ± 25
Probe temperature setting, °F	248 ± ~~25~~ 59
Orsat flow rate setting, SCFH	
Meter box operator	
Date	5-10-02

	POINT	CLOCK TIME min	DRY GAS METER CF	PITOT in. H_2O ΔP	ORIFICE ΔH in. H_2O DESIRED	ORIFICE ΔH in. H_2O ACTUAL	PROBE TEMP °F	STACK TEMP °F	DRY GAS TEMP, °F INLET	DRY GAS TEMP, °F OUTLET	FILTER TEMP °F	IMPINGER TEMP °F	PUMP VACUUM in.Hg	ORSAT FLOW SCFH	STATIC PRESSURE ± in.H_2O
Top	1	0	375.778	.014	.65	.65	266	236	~~68~~ 72	~~254~~	254	61	3.7	1.0	—
	1	5	377.62	.014	.65	.65	258	260	—	73	256	59	3.8	1.0	—
	1	10	379.98	.012	.56	.56	261	262	—	73	258	55	3.5	.65	—
	1	15	382.07	.012	.56	.56	260	263	—	73	257	55	3.6	.65	—
Port 1 *	2	20	384.10	.012	.56	.56	261	263	—	73	257	54	3.8	.65	—
	2	25	386.13	.013	.60	.60	261	263	—	74	257	55	4.2	.65	—
	2	30	388.23	.013	.60	.60	261	263	—	74	258	54	4.4	.65	—
	2	35	390.33	.012	.56	.56	261	263	—	74	259	55	4.4	.65	—
*	3	40	392.40	.012	.56	.56	262	261	—	74	257	55	4.6	.55	—
	3	45	394.36	.011	.51	.51	260	260	—	74	260	56	4.8	.50	-16.6
	3	50	396.32	.011	.51	.51	261	260	—	74	258	54	5.0	.45	—
	3	55	398.28	.011	.51	.51	261	261	—	75	257	52	5.2	.45	—
*	4	60	400.25	.010	.46	.46	262	215	—	75	257	52	5.2	.45	—
	4	65	402.13	.010	.46	.46	260	184	—	75	258	52	5.4	.45	—
	4	70	404.00	.010	.46	.46	260	180	—	75	257	52	5.4	.15	—
P	4	75	405.87	.009	.42	.42	261	164	—	75	258	52	5.4	.15	—
*	1	80	407.68	.007	.32	.32	261	115	—	75	258	54	5.4	.15	-16.2
	1	85	409.49	.005	.23	.23	261	188	—	75	249	56	4.5	.00	—
Port 2	1	90	410.92	.006	.28	.28	262	223	—	76	259	57	4.6	0	—
	1	95	412.35	0.006	.28	.28	262	228	—	76	259	58	4.6	0	—
*	2	100	413.77	.006	.28	.28	261	240	—	76	259	57	4.9	0	—
	2	105	415.21	.005	.23	.23	261	259	—	76	258	58	4.8	0	—
	2	110	416.60	.006	.28	.28	262	260	—	76	258	58	4.9	0	—
	2	115	418.00	.006	.28	.28	261	260	—	76	259	57	5.0	0	—
	—	~~120~~	—	~~Post Clean~~	—	—	—	—	—	—	—	—	—	—	—
	Final	—	—												

Nomograph Calibration Variables ΔH@ ~~1.84~~ 07 Cp .84 Ts Tm Ps Pm ΔP Bws

Comments: Port change @ ~~1343~~ 1343 gf

All .006 ΔP = .28 ΔH gf

Test Observers -

Job Number: 020301A ~~-3~~

Done By / Date: gf / 5-10-02

Air Compliance Testing, Inc

Ontario Hydro Isokinetic Field Data

Plant	Powerspan	Meter box no.	T-MTB- 008	Gamma	1.0112
Location	ECO ~~Exhaust Duct~~ Inlet	Pump no.	T-PMP- 008	K Factor	46 / 1
Run no.	3	Nomograph no.	T-NOM- 002	Nozzle Size, in.	0.503
Test start time	12:24	Probe no.	T-PRB- 606	Barometric pressure, in.Hg	29.58
Test stop time	16:28	Filter box no.	T-FLB- 011	Ambient temperature, °F	70
Pre-test leak rate @ 15in.Hg	.000	Impinger box no.	T-IMB- 014	Filter box temperature setting, °F	248 ± 25
Post-test leak rate @ 10 in.Hg	.000	Umbilical cord no.	T-UMC- 601	Probe temperature setting, °F	248 ± 59
Pre-test pitot leak check - ☑ total ☑ static		Umbilical adapter no.	T-UMA- 001	Orsat flow rate setting, SCFH	
Post-test pitot leak check - ☑ total ☑ static		Orsat bag no.	020301A - 3 - OK	Meter box operator	[illegible] Date 5-10-02

	POINT	CLOCK TIME min	DRY GAS METER CF	PITOT in. H_2O ΔP	ORIFICE ΔH in. H_2O DESIRED	ORIFICE ΔH in. H_2O ACTUAL	PROBE TEMP °F	STACK TEMP °F	DRY GAS TEMP °F INLET	DRY GAS TEMP °F OUTLET	FILTER TEMP °F	IMPINGER TEMP °F	PUMP VACUUM in.Hg	ORSAT FLOW SCFH	STATIC PRESSURE ± in.H_2O
*	3	120	419.38	.006	.28	.28	261	260	—	76	259	57	5.0	0	—
Port 2	3	125	420.75	.006	.28	.28	261	262	—	77	258	57	5.0	0	—
	3	130	422.10	.007	~~.28~~ .32	~~.28~~ .32	261	261	—	77	259	56	5.6	0	—
	3	135	423.61	.007	.32	.32	262	261	—	77	258	56	6.1	0	—
*	4	140	425.18	.006	.28	.28	261	261	—	77	258	55	6.1	0	—
	4	145	426.68	.0067	.32	.32	262	261	—	78	258	56	6.0	0	—
	4	150	428.13	.008	.37	.37	262	262	—	78	259	56	6.8	0	—
P	4	155	429.77	.007	.32	.32	263	261	—	78	259	56	7.0	0	—
	1	160	431.45	.004	.19	.19	264	217	—	79	259	58	6.0	0	—
	1	165	433.05	.004	.19	.19	261	250	—	79	259	58	5.9	0	—
	1	170	434.31	.004	.19	.19	261	255	—	79	259	59	6.0	0	—
Port 3	1	175	435.58	.004	.19	.19	261	255	—	79	259	59	6.2	0	—
*	2	180	436.82	.004	.19	.19	262	255	—	80	259	59	6.3	0	—
	2	185	438.07	.004	.19	.19	262	253	—	80	259	59	6.3	0	—
	2	190	439.30	0.004	.19	.19	261	253	—	80	259	59	6.3	0	-15.6
	2	195	440.51	0.004	.19	0.19	261	253	—	80	259	~~60~~ 59	6.3	0	
*	3	200	441.88	0.004	.19	.19	262	249	—	81	259	58	6.4	0	
	3	205	443.01	0.004	.19	.19	262	249	—	81	259	58	6.4		
	3	210	444.22	0.003	0.15	0.15	262	250	—	81	260	58	6.0	1	
	3	215	445.38	0.002	0.092	0.1	261	250	—	81	259	59	5.5	0	
*	4	220	446.27	0.002	0.092	0.1	261	251	—	81	259	60	5.5	0	
	4	225	447.34	0.002	0.092	0.1	261	251	—	81	259	60	5.5	0	
	4	230	448.31	0.006	0.28	0.28	260	215 ~~252~~	—	80	260	60	5.5	0	
	4	235	449.46	0.006	0.28	0.28	261	214	—	80	259	59 61	7.3	0	
	Final	240	450.881												

Nomograph Calibration Variables ΔH@ 1.8407 Cp .84 Ts Tm Ps Pm ΔP Bws

Comments: Port change @ 1504 - 1508 Restart | Leak Check
All .006 ΔP are .28 ΔH 431.624 → 431.697 → 0.073

Test Observers -

Job Number: 020301A
Done By / Date: [illegible] / 5-10-02

Air Compliance Testing, Inc.

Ontario Hydro Moisture Recovery

Plant Name Powerspan Location ECO ~~Exhaust~~ Inlet Duct

Reagents Prepared By / Date TS / 5.8.02

Run Number	1			2		
Run Date	5.8.02			-		
Analysis Date	5.9.02			-		
Time of Analysis	731			-		
Turbidity / Color (Clear, Cloudy, Suspended Particulates, etc.)	KCl - clear HNO_3/H_2O_2 - clear $KMnO_4$ - purple/brown			-		
REAGENT #1	KCl			KCl		
Final Weight (g)	760.5	688.6	642.3	-	-	-
Tared Weight (g)	685.8	664.4	638.7	-	-	-
Condensed H_2O (g)	74.7	24.2	3.6	-	-	-
REAGENT #2	HNO_3 / H_2O_2			HNO_3 / H_2O_2		
Final Weight (g)	678.4			-		
Tared Weight (g)	671.1			-		
Condensed H_2O (g)	7.3			-		
REAGENT #3	$KMnO_4$			$KMnO_4$		
Final Weight (g)	677.4	694.5	622.7	-	-	-
Tared Weight (g)	676.1	668.0	650.4	-	-	-
Condensed H_2O (g)	1.3	26.5	-27.7	-	-	-
Total Condensed (g)	109.7			-		
SILICA GEL						
Final Weight (g)	859.4			-		
Tared Weight (g)	845.4			-		
Adsorbed H_2O (g)	14.0			-		
Total H_2O Collected (g)	123.7			-		
Analytical Balance ID	A - BAL - 004					

Job Number: 020301.1

Done By / Date: KQ / 5.14.02

Checked By / Date: A.N. / 5.31.02

Final Check By / Date: D / 6.10.02

Air Compliance Testing, Inc.

(Ontario Hydro.xls-Moisture Recovery) 3/8/2002

Ontario Hydro Moisture Recovery

Plant Name Powerspan | Location ECO Inlet Duct

Reagents Prepared By / Date TS / 5·9·02

	Run 2			Run 3		
Run Number	2			3		
Run Date	5·10·02			5 10 02		
Analysis Date	5·10·02			5·13·02		
Time of Analysis	1205			10 30		
Turbidity / Color (Clear, Cloudy, Suspended Particulates, etc.)	KCl - clear HNO_3/H_2O_2 - clear $KMnO_4$ - Purple/brown			KCl - clear HNO_3/H_2O_2 - clear $KMnO_4$ - purple brown		
REAGENT #1	KCl			KCl		
Final Weight (g)	691.2	720.4	666.2	~~619.0~~ 719.0	683.3	578.1
Tared Weight (g)	615.8	686.8	659.0	660.4	657.8	572.4
Condensed H_2O (g)	75.4	33.6	7.2	58.6	25.5	5.7
REAGENT #2	HNO_3 / H_2O_2			HNO_3 / H_2O_2		
Final Weight (g)	707.1			680.2		
Tared Weight (g)	695.6			671.1		
Condensed H_2O (g)	11.5			9.1		
REAGENT #3	$KMnO_4$			$KMnO_4$		
Final Weight (g)	692.7	695.3	648.6	674.9	609.7	677.3
Tared Weight (g)	689.5	694.9	648.7	672.5	609.4	677.4
Condensed H_2O (g)	3.2	6.4	-0.1	2.4	0.3	-0.1
Total Condensed (g)	131.2			101.5		
SILICA GEL						
Final Weight (g)	837.7			879.7		
Tared Weight (g)	817.8			863.1		
Adsorbed H_2O (g)	19.9			16.6		
Total H_2O Collected (g)	151.1			118.1		

Analytical Balance ID A - BAL - 004

Job Number: 020301A
Done By / Date: KR / 5·14·02
Checked By / Date: AN / 5·31·02 : KR 6·4·02
Final Check By / Date: D 6·10·02

Air Compliance Testing, Inc.
(Ontario Hydro xls-Moisture Recovery) 3/8/2002

Method 3 Orsat Field Data

Plant Name: Powerspan Fuel Type:

Sampling Location: ECO Exhaust Duct INLET

Pre-Test Leak Check: ✓ Post-Test Leak Check:

Run Number: 1		Date: 5-8-02 AN				Operator: KR / SAC	
Time of Sample Collection	Time of Analysis	CO_2 Reading (A)	O_2 Reading (B)	CO Reading (C)	$\%O_2$ (B-A)	%CO (C-B)	$\%N_2$ (100-C)
18:50	13 30	10.8	19.4	19.4	8.6	0.0	80.6
↓ AN	14 16	10.6	18.0	17.9	7.4	-0.01	82.1
21:53	1500	10.9	19.2	19.4	8.3	0.2	80.6
	Average	10.77	-	-	8.1	0.03	~~81.07~~ 81.10

Analyzer I.D. - A-ORS-001 Tedlar Bag I.D. - 020301A-1-OR F_o = 1.187

Run Number: 2		Date: 5-9-02				Operator: CB	
Time of Sample Collection	Time of Analysis	CO_2 Reading (A)	O_2 Reading (B)	CO Reading (C)	$\%O_2$ (B-A)	%CO (C-B)	$\%N_2$ (100-C)
7:50	13:12	10.3	18.8	18.9	8.5	0.1	81.1
↓ AN	13:30	10.2	18.8	18.8	8.6	0.0	81.2
11:57	13:43	10.3	18.9	18.9	8.6	0.0	81.1
	Average	10.27	-	-	8.57	0.03	81.13

Analyzer I.D. - A ORS-001 Tedlar Bag I.D. - 020301A-2-OR F_o = 1.199

Run Number: 3		Date: 5-9-02				Operator: CB	
Time of Sample Collection	Time of Analysis	CO_2 Reading (A)	O_2 Reading (B)	CO Reading (C)	$\%O_2$ (B-A)	%CO (C-B)	$\%N_2$ (100-C)
12:24	14:07	10.5	19.0	19.0	8.5	0.0	81.0
↓ AN	14:24	10.5	19.0	19.0	8.5	0.0	81.0
16:20	14:48	10.5	19.0	19.0	8.5	0.0	81.0
	Average	10.5	~~19.0~~	-	8.5	0.0	81.0

Analyzer I.D. - A-ORS-001 Tedlar Bag I.D. - 020301A-3-OR F_o = 1.181

Job Number: 020301A

Done By / Date: CB / 5-16-02

Checked By / Date: AN / 5-31-02 KC / 6-4-02

Final Check By / Date: D / 6-10-02

Method 3 Dry Molecular Weight Calculation

Run 1 — Fo= 1.187

	CO2 Reading	O2 Reading	CO Reading	%O2	%CO	%N2	Molecular Weight	Mean Difference
	10.80	19.40	19.40	8.60	0.00	80.60	30.072	0.025
	10.60	18.00	17.90	7.40	-0.10	82.10	29.992	-0.055
	10.90	19.20	19.40	8.30	0.20	80.60	30.076	0.029
Average	10.77			8.10	0.03	81.10	30.05	

Run 2 — Fo= 1.199

	CO2 Reading	O2 Reading	CO Reading	%O2	%CO	%N2	Molecular Weight	Mean Difference
	10.30	18.80	18.90	8.50	0.10	81.10	29.988	0.003
	10.20	18.80	18.80	8.60	0.00	81.20	29.976	-0.009
	10.30	18.90	18.90	8.60	0.00	81.10	29.992	0.007
Average	10.27			8.57	0.03	81.13	29.99	

Run 3 — Fo= 1.181

	CO2 Reading	O2 Reading	CO Reading	%O2	%CO	%N2	Molecular Weight	Mean Difference
	10.50	19.00	19.00	8.50	0.00	81.00	30.020	0.000
	10.50	19.00	19.00	8.50	0.00	81.00	30.020	0.000
	10.50	19.00	19.00	8.50	0.00	81.00	30.020	0.000
Average	10.50			8.50	0.00	81.00	30.02	

Inlet

Job Number: 020301A
Done By / Date: KR 16 4 02
Checked By / Date: ___ / ___ : ___ / ___
Final Check By / Date: [illegible] / 6-10-02

Air Compliance Testing, Inc.
(Molecular Weight Calculator.xls-Orsat Field Data) 6/4/02

Method 1 Preliminary Field Data

Plant	Powerspan
City, State	Shadyside, Ohio
Location	ECO Inlet Duct

Duct Depth (Inner Diameter):

	TOP (1)	MID	BOT
Relative Location	TOP	MID	BOT
From Far Inside Wall to Outside of Port (in.)	30.2	30.2	30.2
Nipple Length and/or Wall Thickness (in.)	6.2	6.2	6.2
Nipple Protrusion (in.)	0	0	0
Stack or Duct Depth (Inner Diameter) (in.)	24	24	24
Stack or Duct Width (Only If Rectangular) (in.)	24	24	24
Stack Outer Circumference (in.)	—	—	—
Port Hole Inner Diameter (in.)	4	4	4

Equivalent Diameter = D_e

$$D_e = \frac{2 \times \text{Depth} \times \text{Width}}{\text{Depth} + \text{Width}} = \frac{2(24)(24)}{(24)+(24)} = 24$$

Distance Upstream from Flow Disturbance	82"
Diameters Upstream from Flow Disturbance (≥0.5 D_e)	3.42
Minimum Traverse Points Needed *	12

Distance Downstream from Flow Disturbance	223
Diameters Downstream from Flow Disturbance (≥2 D_e)	9.29
Minimum Traverse Points Needed *	12

*Circle Larger of the Two

Stack or Duct Area = ~~24 x~~ A.N. 576 in.^{2}

Location of Points in Circular Stacks or Ducts

	4	6	8	10	12	14	16	18	20	22	24
1	6.7	4.4	3.2	2.6	2.1	1.8	1.6	1.4	1.3	1.1	1.1
2	25.0	14.6	10.5	8.2	6.7	5.7	4.9	4.4	3.9	3.5	3.2
3	75.0	29.6	19.4	14.6	11.8	9.9	8.5	7.5	6.7	6.0	5.5
4	93.3	70.4	32.3	22.6	17.7	14.6	12.5	10.9	9.7	8.7	7.9
5		85.4	67.7	34.2	25.0	20.1	16.9	14.6	12.9	11.6	10.5
6		95.6	80.6	65.8	35.6	26.9	22.0	18.8	16.5	14.6	13.2
7			89.5	77.4	64.4	36.6	28.3	23.6	20.4	18.0	16.1
8			96.8	85.4	75.0	63.4	37.5	29.6	25.0	21.8	19.4
9				91.8	82.3	73.1	62.5	38.2	30.6	26.2	23.0
10				97.4	88.2	79.9	71.7	61.8	38.8	31.5	27.2
11					93.3	85.4	78.0	70.4	61.2	39.3	32.3
12					97.9	90.1	83.1	76.4	69.4	60.7	39.8
13						94.3	87.5	81.2	75.0	68.5	60.2
14						98.2	91.5	85.4	79.6	73.8	67.7
15							95.1	89.1	83.5	78.2	72.8
16							98.4	92.5	87.1	82.0	77.0
17								95.6	90.3	85.4	80.6
18								98.6	93.3	88.4	83.9
19									96.1	91.3	86.8
20									98.7	94.0	89.5
21										96.5	92.1
22										98.9	94.5
23											96.8
24											98.9

Location of Points in Rectangular Stacks or Ducts

	2	3	4	5	6	7	8	9	10	11	12
1	25.0	16.7	12.5	10.0	8.3	7.1	6.3	5.6	5.0	4.5	4.2
2	75.0	50.0	37.5	30.0	25.0	21.4	16.8	16.7	15.0	13.6	12.5
3		83.3	62.5	50.0	41.7	35.7	31.3	27.8	25.0	22.7	20.6
4			87.5	70.0	58.3	50.0	43.8	38.9	35.0	31.8	29.2
5				90.0	75.0	64.3	56.3	50.0	45.0	40.9	37.5
6					91.7	78.6	68.7	61.1	55.0	50.0	45.8
7						92.9	81.3	72.2	65.0	59.1	54.2
8							93.8	83.3	75.0	68.2	62.5
9								94.4	85.0	77.3	70.8
10									95.0	86.4	79.2
11										95.5	87.5
12											95.8

Note:

1) Stacks having a diameter greater than 24in, shall have no traverse points located within 1.0in of the Stack walls.

2) Stacks having a diameter less than or equal to 24in, shall have no traverse points located within .50in of the Stack walls.

Relocate to a distance equal to the inside diameter of the nozzle being used or to the above minimum distances, whichever is larger.

Number of Ports:	3
Direction of Flow:	R to L ←
Isokinetic Sample:	Yes / No
Stack Build-up:	Yes / No

11.9" NIPPLE LENGTH FOR FLOWS

5.7" ADDITIONAL PORT LENGTH FOR FLOWS

Point	% of Duct Depth	Distance From Inside Wall (in.)		Distance From Outside of Port (in.)	
-	-	Port 1	Port 2	Port 1	Port 2
1	12.5	3.0	–	20.6	–
2	37.5	9.0	–	26.6	–
3	62.5	15.0	-	32.6	–
4	87.5	21.0	–	38.6	–
5					
6					
7					
8					
9					
10					
11					
12					
	FLOWS			14.9	
				20.9	
				26.9	
				32.9	

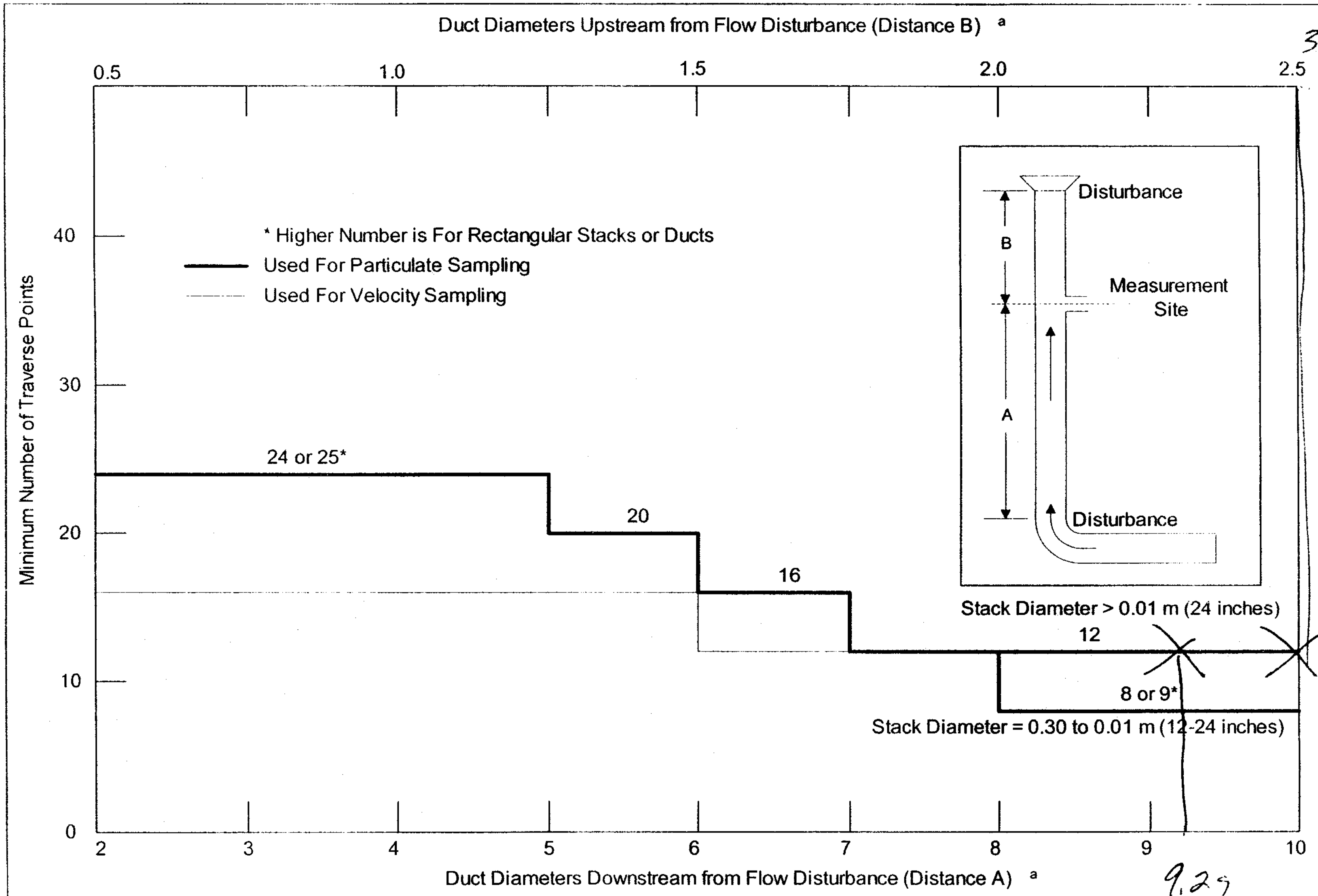
Job Number: ~~0204~~ 020301

Done By / Date: JH / 5 8 02

Checked By / Date: A.N. / 5-22-02 KR / 6 4 02

Final Check By / Date: [illegible] / 6 10 02

Method 1 Criteria Data



[a] From point of any type of disturbance (bend, expansion contraction, etc.)

Test Location ECO Inlet Duct

Job Number: 020361
Done By / Date: KC / 5/8/02
Checked By / Date: A.N. / 5-22-02 KR / 6-4-02
Final Check By / Date: D / 6-10-02

Ontario Hydro Isokinetic Field Data

Plant	Powerspan	Meter box no.	T-MB- 008	Gamma	1.0112
Location	ECO ~~Inlet~~ Duct Exhaust	Pump no.	T-PMP- 008	K Factor	45 / 154 @ 60 /
Run no.	21	Nomograph no.	T-NOM- 002	Nozzle Size, in.	0.503
Test start time	8 25	Probe no.	T-PRB- 606	Barometric pressure, in.Hg	29.20
Test stop time	11 30 AM	Filter box no.	T-FLB- 006	Ambient temperature, °F	72
Pre-test leak rate @ 15in.Hg	0.0015	Impinger box no.	T-IMB- 009	Filter box temperature setting, °F	248 ± 25
Post-test leak rate @ in.Hg	0.001 AH	Umbilical cord no.	T-UMC- 304	Probe temperature setting, °F	248 ± 59
Pre-test pitot leak check - ✓ total ✓ static		Umbilical adapter no.	T-UMA- 003	Orsat flow rate setting, SCFH	0.222
Post-test pitot leak check - total static		Orsat bag no.	~~I~~ 020301-2-OR	Meter box operator	SHC Date 05 09 02

POINT	CLOCK TIME min	DRY GAS METER 45.677 CF	PITOT In. H_2O ΔP	ORIFICE ΔH In. H_2O DESIRED	ORIFICE ΔH In. H_2O ACTUAL	PROBE TEMP °F	STACK TEMP °F	DRY GAS TEMP, °F INLET	DRY GAS TEMP, °F OUTLET	FILTER TEMP °F	IMPINGER TEMP °F	PUMP VACUUM in.Hg	ORSAT FLOW SCFH	STATIC PRESSURE ± in.H_2O
1	0	~~45.528~~	0.02	0.9	0.9	266	101	~~71~~	~~250~~ 71	259	54	3.0	0.0	~~0~~ -13
1	5 6:30 ~~10~~	48.29	0.02	0.7	0.9	262	134	~~7~~	72	259	52	3.0	0.0	-
1	10 ~~15~~	49.30	0.02	0.9	0.9	261	138	—	72	259	52	3.0	0.0	-
2	15 ~~20~~	51.86	0.01	0.45	0.45	262	148	—	73	259	48	3.9	0.0	-
2	20 ~~25~~	53.99	0.015	0.68	0.68	263	163	—	74	259	50	2.9	9.0	-
2	25 ~~30~~	55.94	0.015	0.68	0.68	263	164	—	75	259	50	3.3	2.0	-
3	30 ~~35~~	58.08	0.01	0.45	0.45	262	164	—	76	259	51	3.3	~~1.70~~	-
3	35 ~~40~~	59.90	0.01	0.45	0.46	261	164	—	76	259	53	3.0	0	-
3	40 ~~45~~	61.61	0.009	0.41	0.41	264	164	—	78	259	54	2.8	0	-
4	45 ~~50~~	63.23	0.009	0.41	0.41	263	165	—	78	260	54	2.8	0	-
4	50 ~~55~~	64.86	0.009	0.41	0.41	263	165	—	79	260	55	2.7	0	-
4	55 ~~60~~	66.49	0.009	0.41	0.41	263	165	—	79	273	55	2.9	0	-
1	60	68.247	0.008	0.34	0.34	262	157	—	80	261	56	2.6	0	-
1	65 ~~70~~	69.76	0.007	0.399	0.40	262	164	—	80	261	56	2.9	0	-
1	70 ~~75~~	71.34	0.007	0.399	0.40	263	164	—	81	261	56	2.9	0	-
2	75 ~~80~~	72.93	0.007	0.399	0.40	262	165	—	81	261	56	2.9	0	-
2	80 ~~85~~	74.51	0.008	0.445	0.45	262	166	—	82	261	56	3.0	0	-
2	85 ~~90~~	76.39	0.008	0.445	0.45	262	166	—	83	261	56	3.0	0	-
3	90 ~~95~~	77.92	0.008	0.445	0.45	288	167	—	83	261	56	3.0	0	-
3	95 ~~100~~	79.62	0.009	0.51	0.51	264	166	—	84	261	56	3.2	0	-
3	100 ~~105~~	81.45	0.009	0.51	0.51	264	166	~	84	262	56	3.2	0	-
4	105 ~~110~~	83.29	0.01	0.561	0.56	264	156	—	84	261	57	3.4	0	-
4	110 ~~115~~	85.22	0.01	0.561	0.56	263	146	—	85	262	57	3.4	0	-
4	115 ~~120~~	87.15	0.01	0.561	0.56	264	146	—	85	262	57	3.4	0	-
Final	~~120~~ 120													

Nomograph Calibration Variables ΔH@ 1.8407 Cp 0.84 Ts ~~80~~ 250 150 Tm 80 Ps 29 Pm 29 ΔP .007 Bws 9%

Comments: PORT CHANGE #1@ 926, #2@10:28, #2@
RESUME @ #2 927, #3@ 10:30

Test Observers -

0.0960
0.0945
0.0015

Job Number: 020301
Done By / Date: SHC / 050902
Final Check By / Date: AN / 5-31-02

Air Compliance Testing, Inc.

(Ontario Hydro xls Isokinetic Field Data) 3/8/2002

Ontario Hydro Isokinetic Field Data (2)

Plant	Powerspan	Meter box no.	1 ;B- 608	Gamma	1.0112
Location	ECO ~~Inlet~~ Duct EXHAUST	Pump no.	T-PMP- 008	K Factor	54 / 61 010%
Run no.	2 1 PORT 3	Nomograph no.	T-NOM- 002	Nozzle Size, in.	0.503
Test start time	—	Probe no.	T-PRB- 606	Barometric pressure, in.Hg	29.25
Test stop time	11:30	Filter box no.	T-FLB- 006	Ambient temperature, °F	
Pre-test leak rate @ 15in.Hg	~~0.00~~ 0.015	Impinger box no.	T-IMB- 009	Filter box temperature setting, °F	248±25
Post-test leak rate @ 4 in.Hg	0.001	Umbilical cord no.	T-UMC- 304	Probe temperature setting, °F	248±25
Pre-test pitot leak check - ✓ total ✓ static		Umbilical adapter no.	T-UMA- 003	Orsat flow rate setting, SCFH	0.222
Post-test pitot leak check - ✓ total ✓ static		Orsat bag no.	020301 ~~-2~~ -2-OR	Meter box operator	SHC Date 05.09.02

	POINT	CLOCK TIME min	DRY GAS METER CF	PITOT In. H_2O ΔP	ORIFICE ΔH In. H_2O DESIRED	ORIFICE ΔH In. H_2O ACTUAL	PROBE TEMP °F	STACK TEMP °F	DRY GAS TEMP, °F INLET	DRY GAS TEMP, °F OUTLET	FILTER TEMP °F	IMPINGER TEMP °F	PUMP VACUUM in.Hg	ORSAT FLOW SCFH	STATIC PRESSURE ± in.H_2O
PORT 3	1	~~125~~ 120	89.36	0.006	0.34	0.34	264	106	~~86~~	~~262~~ 86	262	59	2.9	0	—
	1	125 ~~130~~	90.81	0.006	0.34	0.34	264	109	—	86	262	62	2.9	0	—
	1	130 135	92.31	0.0087	0.429	0.43	265	117	—	87	262	58	3.1	0	—
	2	135 ~~140~~	93.38	0.007	0.429	0.43	262	140	—	87	262	56	3.1	0	—
	2	140 ~~145~~	95.67	0.009	0.55	0.56	263	167	—	87	262	55	3.3	0	—
	2	145 ~~155~~	97.56	~~0.015~~ 0.01	~~0.92~~ 0.62	~~0.92~~ 0.62	263	167	—	88	262	53	3.45	0	—
	3	150 ~~160~~	99.72	0.01	0.62	0.62	263	166	—	88	262	54	3.7	0	—
	3	~~160~~ 155 ~~165~~	101.76	0.01	0.62	0.62	265	166	—	88	262	55	3.5	0	—
	3	~~160~~ 160 ~~170~~	103.81	0.01	0.62	0.62	263	166	—	88	263	55	3.5	0	—
	4	~~170~~ 165 ~~175~~	105.87	0.006	~~0.62~~ 0.34	~~0.62~~ 0.34	264	165	—	88	262	56	3.6	0	—
	4	~~170~~ 170 ~~180~~	107.60	0.006	0.34	0.34	264	163	—	89	262	60	3.0	0	—
BOT	4	~~180~~ 175 ~~180~~	109.108	0.006	0.34	0.34	264	163	—	89	262	62	3.0	0	—
	Final	180.42	110.751												

Nomograph Calibration Variables ΔH@ 1.8407 Cp 0.84 Ts Tm Ps Pm ΔP Bws

Comments.

Test Observers -

0.078
0.077
0.001

Air Compliance Testing, Inc.
(Ontario Hydro xls-Isokinetic Field Data (2)) 3/8/2002

Job Number: 020301
Done By / Date: SHC / 05.09.02
Final Check By / Date: A.W. / 5-31-02

Ontario Hydro Isokinetic Field Data (4)

Plant	Powerspan	Meter box no.	T-MTB-008	Gamma	1.0112
Location	ECO Exhaust Duct	Pump no.	T-PMP-008	K Factor	/ /
Run no.	~~1~~ 2	Nomograph no.	T-NOM-002	Nozzle Size, in.	.499
Test start time	~~8:26~~ 12:07	Probe no.	T-PRB-~~606~~ 407 JH	Barometric pressure, in.Hg	29.15
Test stop time	16:18 AU.	Filter box no.	T-FLB-~~006~~ 011 JH	Ambient temperature, °F	80
Pre-test leak rate @ 15in.Hg	.002	Impinger box no.	T-IMB-014	Filter box temperature setting, °F	248±25
Post-test leak rate @ 5 in.Hg	0.001 AN	Umbilical cord no.	T-UMC-304	Probe temperature setting, °F	248 ~~± 59~~ + 59 JH
Pre-test pitot leak check - ✓ total	static ✓	Umbilical adapter no.	T-UMA-005	Orsat flow rate setting, SCFH	2.2
Post-test pitot leak check - ✓ total	static ✓	Orsat bag no.	020301-3-02	Meter box operator JH	Date 5-9-02

POINT	CLOCK TIME min	DRY GAS METER CF	PITOT In. H_2O ΔP	ORIFICE ΔH In. H_2O DESIRED	ORIFICE ΔH In. H_2O ACTUAL	PROBE TEMP °F	STACK TEMP °F	DRY GAS TEMP, °F INLET	DRY GAS TEMP, °F OUTLET	FILTER TEMP °F	IMPINGER TEMP °F	PUMP VACUUM in.Hg	ORSAT FLOW SCFH	STATIC PRESSURE ± in.H_2O
1	0	110.[illegible]	.01	.56	.56	267	117	—	88	260	68	3.2	-	-
1	5	112.760	.01	.56	.56	268	115	—	88	263	64	3.2	-	-
1	10	114.875	.01	.56	.56	268	114	—	89	262	60	3.2	-	-
2	15	116.965	.01	.56	.56	271	152	—	89	262	58	3.2	-	-
2	20	119.080	.01	.56	.56	268	165	—	89	262	56	3.0	-	-
2	25	121.200	.01	.56	.56	271	165	—	89	261	55	3.0	-	-
3	30	123.310	.01	.56	.56	267	165	—	89	262	55	3.0	-	-
3	35	125.425	.009	.51	.51	268	165	—	90	261	56	3.1	-	-
3	40	127.435	.009	.51	.51	269	165	—	90	263	57	3.0	-	-
4	45	129.400	.009	.51	.51	268	166	—	90	262	57	3.1	-	-
4	50	131.400	.01	.56	.56	270	165	—	90	262	57	3.2	-	-
4	55	133.480	.009	.51	.51	267	166	—	90	262	57	3.3	-	-
1	60	136.600	.009	.51	.51	270	152	—	90	262	57	3.3	-	-
1	65	137.470	.007	.40	.40	269	164	—	90	262	56	3.0	-	-
1	70	139.355	.007	.40	.40	265	165	—	90	261	56	3.0	-	-
2	75	141.120	.007	.40	.40	270	165	—	90	261	56	3.1	-	-
2	80	142.900	.007	.40	.40	269	165	—	90	262	57	3.0	-	-
2	85	144.[illegible]50	.007	.40	.40	270	165	—	90	261	58	3.0	4	-
3	90	146.490	.007	.40	.40	266	165	—	90	261	59	3.0	4	-
3	95	148.280	.007	.40	.40	271	165	—	90	262	60	3.1	4	-
3	100	150.050	.009	.51	.51	269	167	—	90	262	60	3.5	4	-
4	105	152.030	.009	.51	.51	269	153	—	90	263	59	3.4	6	-
4	110	154.040	.009	.51	.51	271	137	—	89	261	59	3.5	5.5	-
4	115	156.015	.009	.51	.51	267	147	—	89	262	60	3.4	5.5	-
	120	158.005	.006	.255	.255	270	154	—	89	263	62	3.1	0	-
Final														

Nomograph Calibration Variables ΔH@ 1.8407 Cp .84 Ts Tm Ps Pm ΔP Bws

Comments: Port Change 1: 13:08 - 13:40 Port Change 2: 14:08 - 14:09

Test Observers -

Job Number: 020301
Done By / Date: JH / 5-9-02
Final Check By / Date: [illegible] / 5-31-02

Air Compliance Testing, Inc.

(Ontario Hydro xls Isokinetic Field Data (4)) 3/8/2002

Plant	Powerspan	Meter box no.	T-MB- 008	Gamma	1.0112
Location	ECO Exhaust Duct	Pump no.	T-PMP- 008	K Factor	/ /
Run no.	2	Nomograph no.	T-NOM- 002	Nozzle Size, in.	.499
Test start time	12:07	Probe no.	T-PRB- 006	Barometric pressure, in.Hg	—
Test stop time	16:18	Filter box no.	T-FLB- 006	Ambient temperature, °F	80°
Pre-test leak rate @ 15in.Hg	.002	Impinger box no.	T-IMB- 014	Filter box temperature setting, °F	248 ± 25
Post-test leak rate @ 5 in.Hg	0.001	Umbilical cord no.	T-UMC- 304	Probe temperature setting, °F	248 ± 59
Pre-test pitot leak check - ✓ total	✓ static	Umbilical adapter no.	T-UMA- 005	Orsat flow rate setting, SCFH	4.0
Post-test pitot leak check - ✓ total	✓ static	Orsat bag no.	020301-3-OR	Meter box operator	Date 5-9-02

	POINT	CLOCK TIME min	DRY GAS METER CF	PITOT In. H_2O ΔP	ORIFICE ΔH In. H_2O DESIRED	ORIFICE ΔH In. H_2O ACTUAL	PROBE TEMP °F	STACK TEMP °F	DRY GAS TEMP, °F INLET	DRY GAS TEMP, °F OUTLET	FILTER TEMP °F	IMPINGER TEMP °F	PUMP VACUUM in.Hg	ORSAT FLOW SCFH	STATIC PRESSURE ± in.H_2O
125	1	~~120~~	159.780	.005	.22	.22	267	163	–	89	261	63	2.9	0	-13.7
130	1	125	161.175	.006	.255	.255	266	163	–	89	263	62	3.1	0	–
135	1	130	162.645	.006	.255	.255	271	165	–	89	261	58	3.0	0	–
140	2	135	164.105	.006	.255	.255	266	165	–	89	262	57	2.9	0	–
145	2	140	165.550	.007	.24	.24	267	165	–	90	263	57	2.9	0	–
150	2	145	166.080	.009	.305	.305	271	167	–	90	261	57	3.0	~~0~~ 1	–
155	3	150	168.505	.009	.305	.305	271	166	–	90	262	57	3.0	1	–
160	3	155	170.065	.009	.305	.305	271	166	–	90	262	58	3.2	1.5	–
165	3	160	171.635	.008	.275	.275	268	128	–	91	262	59	3.0	0	–
170	4	165	173.175	.008	.275	.275	268	116	–	90	263	59	3.2	0	–
175	4	170	174.685	.007	.24	.24	268	116	–	91	263	60	3.0	0	–
180	4	175	176.105	.009	.305	.305	270	115	–	91	262	58	3.2	0	–
	~~1~~	~~180~~	~~620~~	~~.007~~	~~.24~~	~~.24~~	~~268~~	~~116~~		~~91~~	~~261~~	~~59~~	~~3.1~~	~~0~~	
185	2	185	177.620	.009	.305	.305	269	155	–	91	261	58	3.2	0	–
190	3	190	179.285	.008	.275	.275	266	165	–	91	263	58	3.0	0	–
195	4	195	180.795	.007	.24	.24	271	164	–	90	262	59	3.0	0	–
200	5	200	182.245	.009	.42	.42	267	148	–	90	261	60	3.4	0	–
	6	205	183.865	.009	.42	.42	271	165	–	90	261	57	3.4	0	–
	7.	210	185.690	~~.01~~ .01	.46	.46	267	167	–	90	262	57	3.8	0	–
	8	215	187.590	~~.1~~ .011	.51	.51	269	133	–	90	261	58	3.8	5.5	–
	9	220	189.645	.007	.32	.32	271	106	–	90	262	60	3.4	2	–
	10	225	191.485	.008	.37	.37	268	130	–	90	262	60	3.4	3.5	–
	11	230	193.210	.007	.32	.32	269	154	–	90	262	60	3.3	2	-13.2
	12	235	194.840	.006	.28	.28	269	165	–	90	262	61	3.2	0	–
	Final	240'	196.370												

Nomograph Calibration Variables ΔH@ 1.8407 Cp .84 Ts Tm Ps Pm ΔP Bws

Comments: 240' 25"

Test Observers - Port change 1530 - 1532 15-156 1558

Job Number: 020301

Done By / Date: [initials] / 5-9-02

Final Check By / Date: [initials] / 5-31-02

Air Compliance Testing, Inc.

(Ontario Hydro xls-Isokinetic Field Data) 3/8/2002

Ontario Hydro Is netic Field Data

Plant	Powerspan	Meter box no.	T-MTB- 008	Gamma	1.0112
Location	ECO Exhaust Duct	Pump no.	T-PMP- 008	K Factor	~~4~~ 4.71 /
Run no.	3A	Nomograph no.	T-NOM- 002	Nozzle Size, in.	0.503
Test start time	1658	Probe no.	T-PRB- 606	Barometric pressure, in.Hg	29.15
Test stop time	2102	Filter box no.	T-FLB- 011	Ambient temperature, °F	80 AN
Pre-test leak rate @ 15in.Hg	.003	Impinger box no.	T-IMB- 013	Filter box temperature setting, °F	248 ± 25
Post-test leak rate @ 7.5 in.Hg	0.001	Umbilical cord no.	T-UMC- 304	Probe temperature setting, °F	248 ± 25
Pre-test pitot leak check - ☑ total ☑ static		Umbilical adapter no.	T-UMA- 001	Orsat flow rate setting, SCFH	0.20
Post-test pitot leak check - ☑ total ☑ static		Orsat bag no.	020301-B-2	Meter box operator	SHC Date 5-9-02

POINT	CLOCK TIME min	DRY GAS METER CF	PITOT in. H_2O ΔP	ORIFICE ΔH in. H_2O DESIRED	ORIFICE ΔH in. H_2O ACTUAL	PROBE TEMP °F	STACK TEMP °F	DRY GAS TEMP °F INLET	DRY GAS TEMP °F OUTLET	FILTER TEMP °F	IMPINGER TEMP °F	PUMP VACUUM in.Hg	ORSAT FLOW SCFH	STATIC PRESSURE ± in.H_2O
** 1	0	196.699	0.01	0.46	0.46	268	129	—	85	257	67	5.5	0.22	-14
** 1	5	198.38	0.01	0.46	0.46	258	165	—	86	259	65	5.3	0.22	—
** 1	10	200.10	0.01	0.46	0.46	262	165	—	86	259	62	5.5	0.22	—
* 1	15	202.12	0.01	0.47	0.47	262	165	—	86	260	61	5.5	0.22	—
2	20	203.99	0.007	0.33	0.33	262	165	—	86	261	60	4.5	~~0.22~~	—
2	25	205.462	0.007	0.33	0.33	263	165	—	86	261	59	4.5	0.2	—
2	30	207.24	0.008	0.379	0.38	263	165	—	87	261	59	4.9	0.22	—
2	35	208.93	0.009	0.421	0.42	263	165	—	87	261	59	5.0	0.23	—
3	40	210.73	0.008	0.379	0.38	263	165	—	87	261	59	5.0	0.22	—
3	45	212.49	0.008	0.379	0.38	262	165	—	87	261	59	5.0	0.2	—
3	50	214.20	0.008	0.379	0.38	263	165	—	88	261	59	4.9	0.2	—
3	55	215.92	0.008	0.379	0.38	263	165	—	88	263	59	5.1	0.2	—
4	60	217.64	0.009	0.421	0.42	263	165	—	88	262	60	5.0	0.2	—
4	65	219.242	0.009	0.421	0.42	263	153	—	88	261	60	5.0	0.2	—
4	70	221.22	0.007	0.33	0.33	263	151	—	87	261	61	4.7	0.3	—
4	75	222.84	0.009	0.421	0.42	263	151	—	87	261	61	4.7	0.2	—
1	80	224.45	0.009	0.421	0.42	263	151	—	88	261	61	4.9	0.2	—
1	85	226.31	0.017	0.8 ~~0.52~~	0.8 ~~0.52~~	262	141 ~~138~~	—	87	261	59	7.2	0.2	—
1	90	228.75	0.013	0.61	0.60	262	156	—	87	260	57	6.4	0.2	—
1	95	230.93	0.013	0.61	0.60	261	157	—	87	262	58	6.3	0.2	—
2	100	233.16	0.015	0.705	0.71	262	164	—	87	261	58	6.9	0.2	—
2	105	235.35	0.015	0.705	0.71	262	167	—	86	261	58	6.9	0.2	—
2	110	237.66	0.015	0.705	0.71	262	167	—	86	261	59	6.9	0.2	—
2	115	239.97	0.015	0.705	0.71	262	167	—	87	262	60	7.0	0.2	—
	~~120~~	~~242~~ SHC												
Final														

Port 1 · Port 2

Nomograph Calibration Variables ΔH@ 1.841 Cp .84 Ts 160 Tm 90 Ps 29 Pm 29 ΔP Bws 15

Comments: *@K-FACTOR=47 TO PORT #2 @ 1819 TO PORT #3 @ 1942 TO PORT #4 @
**@K-FACTOR=46 RESUME #2 @ 1920 #3 @ 1943 #4 @

Test Observers -

196.699

Job Number: 020301B
Done By / Date: SHC 1050902
Final Check By / Date: [illegible]

Ontario Hydro I . inetic Field Data

Plant	Powerspan	Meter box no.	T-MTB- 008	Gamma	1.0112
Location	ECO Exhaust Duct	Pump no.	T-PMP- 008	K Factor	47 / /
Run no.	3	Nomograph no.	T-NOM- 002	Nozzle Size, in.	0.503
Test start time	—	Probe no.	T-PRB- 606	Barometric pressure, in.Hg	29.15
Test stop time	— 21 02	Filter box no.	T-FLB- 011	Ambient temperature, °F	80
Pre-test leak rate @ 15in.Hg	—	Impinger box no.	T-IMB- 013	Filter box temperature setting, °F	248 ± 25
Post-test leak rate @ 7.5 in.Hg	0.001	Umbilical cord no.	T-UMC- 304	Probe temperature setting, °F	248 ± 25
Pre-test pitot leak check - ~~total~~ ~~static~~		Umbilical adapter no.	T-UMA- 001	Orsat flow rate setting, SCFH	0.2
Post-test pitot leak check - ~~total~~ ~~static~~		Orsat bag no.	020301-~~4B~~3-OR	Meter box operator	SHC Date 8/9/02

port 2

POINT	CLOCK TIME min	DRY GAS METER CF	PITOT in. H_2O ΔP	ORIFICE ΔH in. H_2O DESIRED	ORIFICE ΔH in. H_2O ACTUAL	PROBE TEMP °F	STACK TEMP °F	DRY GAS TEMP °F INLET	DRY GAS TEMP °F OUTLET	FILTER TEMP °F	IMPINGER TEMP °F	PUMP VACUUM in.Hg	ORSAT FLOW SCFH	STATIC PRESSURE ± in.H_2O
3	120	242.28	0.015	0.705	0.71	261	166	—	86	260	61	7.1	2.0	—
3	125	244.57	0.012	0.561	0.56	262	~~16~~ 166	—	86	262	63	7.1	2.0	—
3	130	246.68	0.011	0.519	0.52	263	166	—	86	261	60	7.1	2.0	—
3	135	248.68	0.011	0.519	0.52	262	166	—	86	261	58	7.2	2.0	—
4	140	250.67	0.010	0.47	0.47	263	165	—	86	261	57	6.7	2.0	—
4	145	252.57	0.010	0.47	0.47	263	165	—	86	261	58	6.5	2.0	—
4	150	254.47	0.010	0.47	0.47	263	165	—	86	261	59	6.1	2.0	—
4	155	256.36	0.010	0.47	0.47	263	165	—	86	261	60	6.1	2.0	—
1	160	258.25	0.007	0.33	0.33	264	135	—	86	261	63	5.0	2.0	—
1	165	260.05	0.007	0.33	0.33	262	160	—	86	261	61	5.0	2.0	—
1	170	261.62	0.008	0.379	0.38	262	162	—	86	261	59	5.1	2.0	—
1	175	263.40	0.005	0.23	0.23	242	142	—	84	242	55	4.0	0.2	—
2	180	264.90	0.007	0.33	0.33	243	164	—	84	241	54	4.8	0.2	—
2	185	266.45	0.006	0.28	0.28	243	165	—	86	242	53	4.8	0.2	—
2	190	268.00	0.006	0.28	0.28	245	165	—	86	241	53	4.8	~~2.0~~	—
2	195	269.45	0.007	0.33	0.33	243	164	—	84	241	53	5.0	0.2	-14.2
3	200	271.25	0.008	0.38	0.38	242	164	—	86	261	52	5.0	0.2	—
3	205	272.85	0.008	0.38	0.38	241	167	—	85	261	52	5.0	0.2	—
3	210	274.60	0.009	0.421	0.42	262	167	—	85	261	52	5.9	0.2	—
3	215	276.43	0.009	0.421	0.42	263	167	—	85	261	52	6.0	0.2	—
4	220	278.27	0.009	0.421	0.42	263	167	—	85	260	53	5.5	0.2	—
4	225	279.93	0.007	0.33	0.33	262	122	—	85	260	54	4.9	0.2	—
4	230	281.54	0.007	0.33	0.33	262	119	—	85	261	55	5.0	0.1	—
4	235	283.18	0.005	0.23	0.23	262	118	—	85	261	56	4.2	~~0~~	—
	~~245~~													
Final	240	284.559												

port 3

out

Nomograph Calibration Variables ΔH@ 1.8407 Cp .84 Ts 160 Tm 90 Ps 29 Pm 29 ΔP Bws

Comments: port change 1943 end

Test Observers -

0.01
0.012

Job Number: 020301-B
Done By / Date: SHC / 05 09 02

Air Compliance Testing, Inc

Ontario Hydro Moisture Recovery

Plant Name Powerspan Location ECO Exhaust Duct

Reagents Prepared By / Date TS / 5.8.02

Run Number	1			2		
Run Date	5.9.02			5.9.02		
Analysis Date	5.9.02			5.9.02		
Time of Analysis	1150			1636		
Turbidity / Color (Clear, Cloudy, Suspended Particulates, etc.)	KCl - Clear HNO_3/H_2O_2 - Clear $KMnO_4$ - purple / brown			KCl - Clear HNO_3/H_2O_2 - clear $KMnO_4$ - Purple / Brown		
REAGENT #1	KCl			KCl		
Final Weight (g)	777.7	721.8	673.2	902.1	627.4	586.5
Tared Weight (g)	618.9	683.1	666.0	668.9	595.4	580.9
Condensed H_2O (g)	158.8	38.7	7.2	233.2	32.0	5.6
REAGENT #2	HNO_3 / H_2O_2			HNO_3 / H_2O_2		
Final Weight (g)	693.2			680.5		
Tared Weight (g)	690.3			676.7		
Condensed H_2O (g)	2.9			3.8		
REAGENT #3	$KMnO_4$			$KMnO_4$		
Final Weight (g)	689.6	691.1	657.2	594.4	605.9	675.7
Tared Weight (g)	687.7	690.0	657.1	593.7	605.5	675.4
Condensed H_2O (g)	1.9	1.1	0.1	0.7	0.4	0.3
Total Condensed (g)	210.7			276.0		
SILICA GEL						
Final Weight (g)	887.6			899.7		
Tared Weight (g)	873.5			881.6		
Adsorbed H_2O (g)	14.1			18.1		
Total H_2O Collected (g)	224.8			294.1		

Analytical Balance ID A - BAL - 004

Job Number: 020301B

Done By / Date: TS / 5.9.02

Checked By / Date: A.N. / 5.31.02 ; KR / 6.4.02

Final Check By / Date: D / 6.10.02

Air Compliance Testing, Inc.

(Ontario Hydro.xls-Moisture Recovery) 3/8/2002

Ontario Hydro Moisture Recovery

Plant Name Powerspan | Location ECO Exhaust Duct

Reagents Prepared By / Date TS / 5·9·02

Run Number	3	—
Run Date	5·9·02	—
Analysis Date	5·10·02	—
Time of Analysis	22:36	—
Turbidity / Color (Clear, Cloudy, Suspended Particulates, etc.)	KCl – clear HNO_3/H_2O_2 – clear $KMnO_4$ – purple/brown	—

REAGENT #1	KCl			KCl		
Final Weight (g)	893.3	693.3	675.5	—	—	—
Tared Weight (g)	676.5	641.0	668.4	—	—	—
Condensed H_2O (g)	216.8	52.3	7.1	—	—	—

REAGENT #2	HNO_3 / H_2O_2	HNO_3 / H_2O_2
Final Weight (g)	668.5	—
Tared Weight (g)	666.3	—
Condensed H_2O (g)	2.2	—

REAGENT #3	$KMnO_4$			$KMnO_4$		
Final Weight (g)	678.6	656.6	689.3	—	—	—
Tared Weight (g)	678.6	656.5	686.9	—	—	—
Condensed H_2O (g)	0.0	0.1	2.4	—	—	—

Total Condensed (g)	280.9	—
SILICA GEL		
Final Weight (g)	901.0	—
Tared Weight (g)	884.3	—
Adsorbed H_2O (g)	16.7	—
Total H_2O Collected (g)	297.6	—

Analytical Balance ID A - BAL - 004

Job Number: 020301B
Done By / Date: TS / 5·10·02
Checked By / Date: AW / 5·31·02 : KC / 6/4/02
Final Check By / Date: [illegible] / 6·10·02

Air Compliance Testing, Inc.
(Ontario Hydro.xls-Moisture Recovery) 3/8/2002

Method 3 Orsat Field Data

Plant Name:	Powerspan	Fuel Type:	
Sampling Location:	ECO ~~Inlet~~ Duct EXHAUST		
Pre-Test Leak Check:		Post-Test Leak Check:	

Run Number: 1 Date: 5-9-02 Operator: ~~SE~~/SC/T1/SH

Time of Sample Collection	Time of Analysis	CO_2 Reading (A)	O_2 Reading (B)	CO Reading (C)	$\%O_2$ (B-A)	%CO (C-B)	$\%N_2$ (100-C)
8:25	1650	9.8	19.4	19.4	9.6	~~9.6~~ 0	80.6
↓ AN	1738	9.9	19.4	19.4	9.5	0	80.6
11:30		10.3	19.7	19.9	9.4	0.2	~~80.1~~ ~~79.9~~ 80.1
	Average	10 AN	-	-	9.5 A.N.	0.07 AN	~~80.1~~ AN 80.4

Analyzer I.D. - A-ORS-001 Tedlar Bag I.D. - 020301B-1-OR F_o = 1.136

Run Number: 2 Date: 5-9-02 Operator: / CS

Time of Sample Collection	Time of Analysis	CO_2 Reading (A)	O_2 Reading (B)	CO Reading (C)	$\%O_2$ (B-A)	%CO (C-B)	$\%N_2$ (100-C)
12:07	2011	8.6	18.1	18.3	9.5	0.2 AN	81.7 AN.
↓	12:12	8.8	19.0	19.1	10.2	0.1	80.9
16:18	12:17	8.7	19.0	19.0	10.3	0.0	81.0
	Average	8.7	-	-	10.00	.10	81.2 AN.

Analyzer I.D. - A-ORS-001 Tedlar Bag I.D. - 020301B-2-OR F_o = 1.244

Run Number: 3 Date: 5-9-02 Operator: CS

Time of Sample Collection	Time of Analysis	CO_2 Reading (A)	O_2 Reading (B)	CO Reading (C)	$\%O_2$ (B-A)	%CO (C-B)	$\%N_2$ (100-C)
16:58	11:11	9.1	18.9	18.9	9.8	0.0	81.1
↓ AN	11:30	9.2	19.0	19.0	9.8	0.0	81.0
21:02	11:45	9.2	19.1	19.1	9.9	0.0	80.9
	Average	9.17	~~19.0~~ AN	-	9.83	0.0	81.0

Analyzer I.D. - A-ORS-001 Tedlar Bag I.D. - 020301B-3-OR F_o = 1.207

Job Number: 020301B
Done By / Date: CS / 5-16-02
Checked By / Date: RC 16 4 02
Final Check By / Date: [illegible] / 6-10-02

Air Compliance Testing, Inc.
(Method 3.xls-Orsat Field Data) 3/8/2002

Method 3 Dry Molecular Weight Calculation

Run 1 Fo= 1.136

	CO2 Reading	O2 Reading	CO Reading	%O2	%CO	%N2	Molecular Weight	Mean Difference
	9.80	19.40	19.40	9.60	0.00	80.60	29.952	-0.028
	9.90	19.40	19.40	9.50	0.00	80.60	29.964	-0.016
	10.30	19.70	19.90	9.40	0.20	80.10	30.024	0.044
Average	10.00			9.50	0.07	80.43	29.98	

Run 2 Fo= 1.244

	CO2 Reading	O2 Reading	CO Reading	%O2	%CO	%N2	Molecular Weight	Mean Difference
	8.60	18.10	18.30	9.50	0.20	81.70	29.756	-0.036
	8.80	19.00	19.10	10.20	0.10	80.90	29.816	0.024
	8.70	19.00	19.00	10.30	0.00	81.00	29.804	0.012
Average	8.70			10.00	0.10	81.20	29.79	

Run 3 Fo= 1.207

	CO2 Reading	O2 Reading	CO Reading	%O2	%CO	%N2	Molecular Weight	Mean Difference
	9.10	18.90	18.90	9.80	0.00	81.10	29.848	-0.012
	9.20	19.00	19.00	9.80	0.00	81.00	29.864	0.004
	9.20	19.10	19.10	9.90	0.00	80.90	29.868	0.008
Average	9.17			9.83	0.00	81.00	29.86	

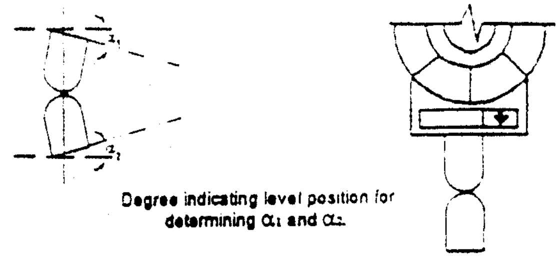
Exhaust

Job Number: 020301B
Done By / Date: KR / 16402
Checked By / Date: — / —
Final Check By / Date: D / 16702

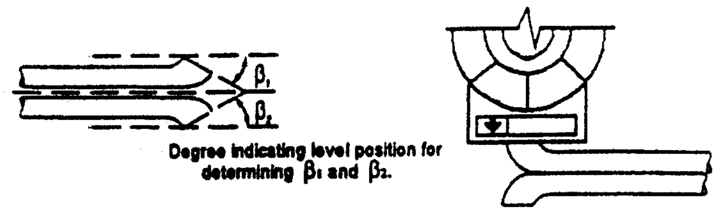
Air Compliance Testing, Inc.
(Molecular Weight Calculator.xls-Orsat Field Data) 6/4/02

Pitot Tube Inspection

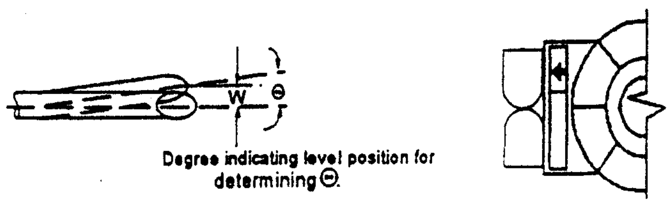
Level and Perpendicular?	yes
Obstructions?	NO
Damaged?	NO
α_1 ($-10° < \alpha_1 < +10°$)	3
α_2 ($-10° < \alpha_2 < +10°$)	7
β_1 ($-5° < \beta_1 < +5°$)	0
β_2 ($-5° < \beta_2 < +5°$)	0
γ	2
θ	0
A	.751
$z = A \tan \gamma$ (< 0.125")	0.026
$w = A \tan \theta$ (< 0.03125")	0
D_t (3/16" < D_t < 3/8")	.251
$1.05D_t < P_A < 1.5D_t$	.376
$1.05D_t < P_B < 1.5D_t$	.375
$P_A = P_B \pm$ 0.063"	.001



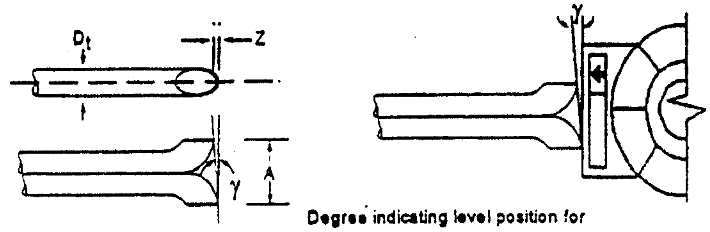
Degree indicating level position for determining α_1 and α_2.



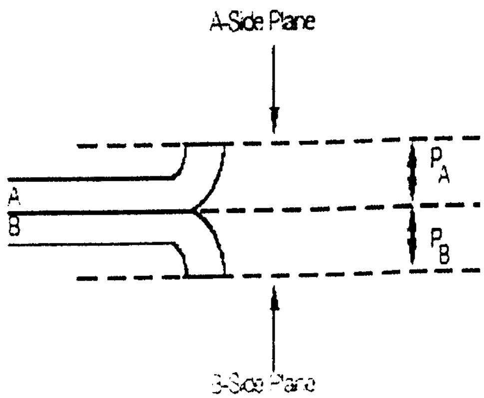
Degree indicating level position for determining β_1 and β_2.



Degree indicating level position for determining Θ.



Degree indicating level position for detemining γ then calculate Z.



I certify that pitot tube / probe number T-PRB-606 meets or exceeds all specifications, criteria and/or applicable design features and is hereby assigned a pitot tube calibration factor of 0.84.

Signature [signature]

Method 4 Probe Minimum Interferences

Probe / Pitot Number: [illegible]

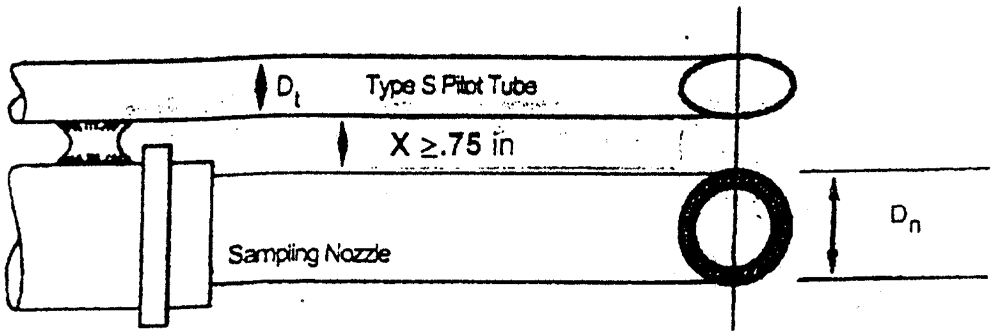
Effective Length: [illegible]

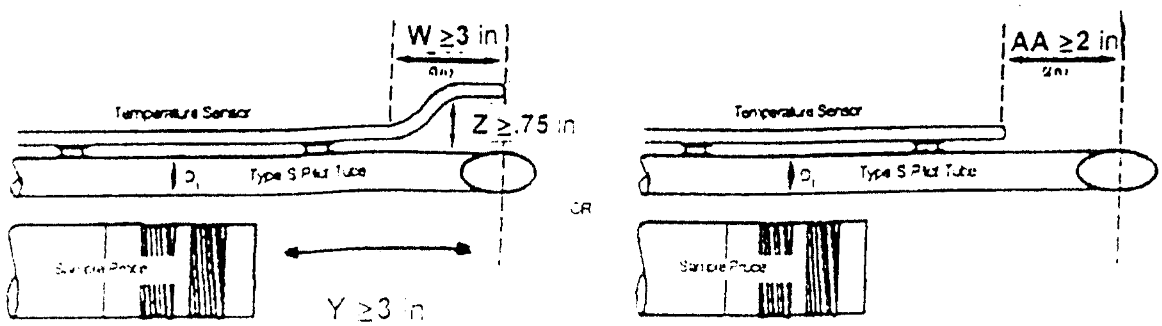
W ($\geq$ 3.0-in) = [illegible] - or - AA ($\geq$ 2.0-in) = [illegible]

X ($\geq$ 0.75-in) = 0.8 - and - X / D_n ($\geq$ 1.5) = 0.8/.493 = 1.62

Y ($\geq$ 3.0-in) = 4.4"

Z ($\geq$ 0.75-in) = NA





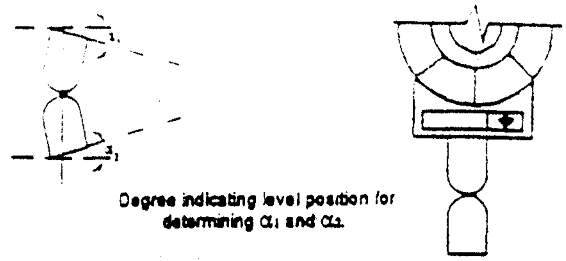
Job Number: [illegible]

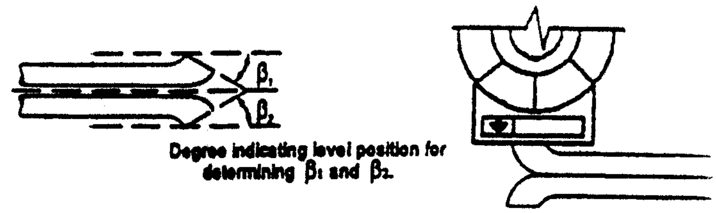
Air Compliance Testing, Inc.

Done By / Date: [illegible] Checked by: ______

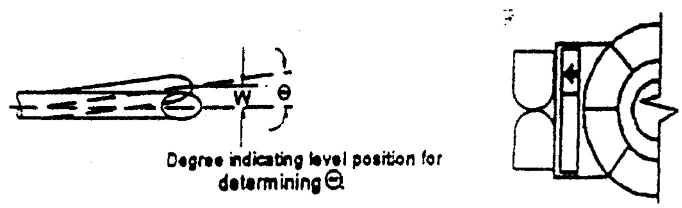
Pitot Tube Inspection

Level and Perpendicular?	Yes
Obstructions?	-
Damaged?	No
α_1 ($-10° < \alpha_1 < +10°$)	1
α_2 ($-10° < \alpha_2 < +10°$)	
β_1 ($-5° < \beta_1 < +5°$)	4
β_2 ($-5° < \beta_2 < +5°$)	3
γ	7
θ	0
A	.759
$z = A \tan\gamma$ (< 0.125")	.093
$w = A \tan\theta$ (< 0.03125")	0
D_t (3/16" < D_t < 3/8")	.252
$1.05D_t < P_A < 1.5D_t$	.372
$1.05D_t < P_B < 1.5D_t$	.387
$P_A = P_B \pm$ 0.063"	.015

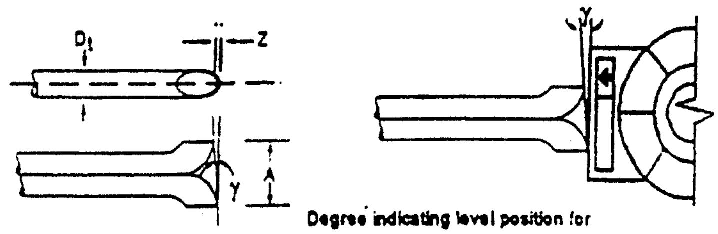

Degree indicating level position for determining α_1 and α_2.



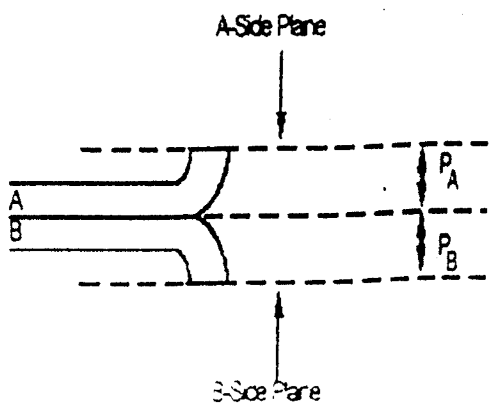
Degree indicating level position for determining β_1 and β_2.



Degree indicating level position for determining θ



Degree indicating level position for detemining γ then calculate Z.



I certify that pitot tube / probe number P-2B-~~466~~ 467 meets or exceeds all specifications, criteria and/or applicable design features and is hereby assigned a pitot tube calibration factor of 0.84.

Signature ______________

Air Compliance Testing, Inc.

Job Number ______

Done By / Date ______

Method 4 Probe Minimum Interferences

Probe / Pitot Number

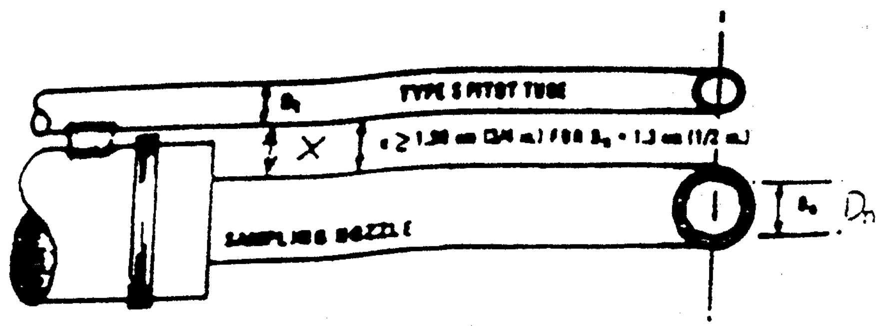
Effective Length

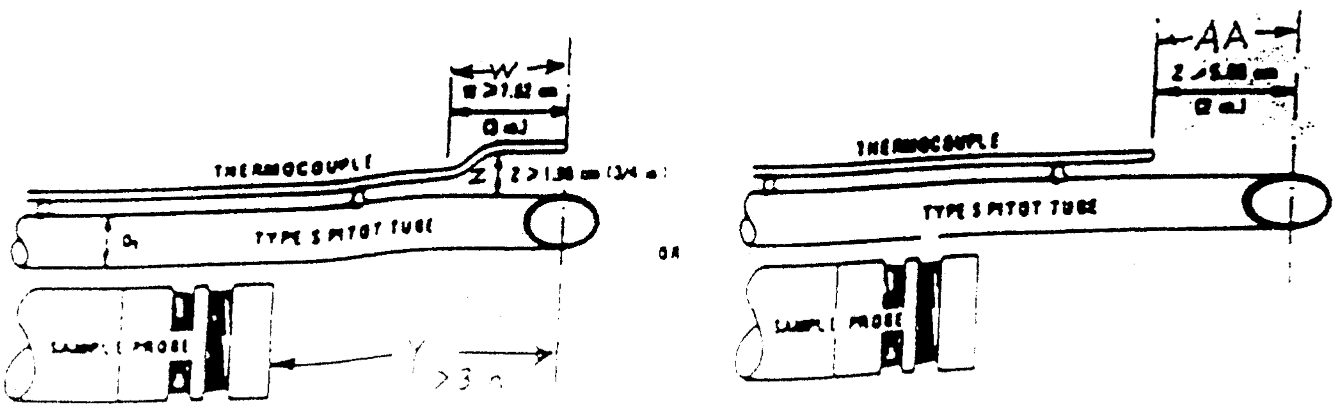
$W \geq 3$in or $AA \geq 2$in. =

$X = >X/D_n$, ratio of >1.5 = 5/.93 = 1.62

$Y = >3$in = 4.2

$Z = >3/4$in = NA





Ontario Hydro Probe Nozzle Inspection

R-1

The probe nozzle should be made of 316 stainless steel or quartz with a sharp, tapered leading .dge. A taper angle of less than or equal to 30 degrees on the outside of the sampling nozzle will preserve a constant internal diameter. The nozzle should be a button-hook or elbow design so that the nozzle opening is below the pitot tube sensing orifice. This is necessary for isokinetic sampling. Alternative construction materials or nozzle shapes must be approved by the administrator.

The sampling nozzle must be calibrated before use in a source experiment. Calibration should be done in the laboratory and checked just before use in the field. Inside / outside calipers are used to measure the interior nozzle diameter to the nearest 0.025mm (0.001 inch).

The calipers are inserted as close to the edge of the nozzle opening as possible; readings are taken on three separate diameters and recorded. Each reading must agree within 0.1 mm (0.004 inch), or the nozzle must be reshaped. Any nozzle that has been nicked, dented, or corroded must be reshaped and recalibrated. All calibrated nozzles should be permanently identified.

Nozzle Number I-7

Marked nozzle size	-	Measured nozzle size	=	X	<= 0.004in
502	-	.502	=	0	<= 0.004in
50.2	-	.502	=	0	<= 0.004in
.502	-	.502	=	0	<= 0.004in

Job Number: 02-0301
Done By / Date: TS / 5-8-02
Final Check By / Date: AW / 5-31-02

Air Compliance Testing, Inc.
(Ontario Hydro.xls-Probe Nozzle Inspection) 3/8/2002

Ontario Hydro Probe Nozzle Inspection (2)

R-2

The probe nozzle should be made of 316 stainless steel or quartz with a sharp, tapered leading edge. A taper angle of less than or equal to 30 degrees on the outside of the sampling nozzle will preserve a constant internal diameter. The nozzle should be a button-hook or elbow design so that the nozzle opening is below the pitot tube sensing orifice. This is necessary for isokinetic sampling. Alternative construction materials or nozzle shapes must be approved by the administrator.

The sampling nozzle must be calibrated before use in a source experiment. Calibration should be done in the laboratory and checked just before use in the field. Inside / outside calipers are used to measure the interior nozzle diameter to the nearest 0.025mm (0.001 inch).

The calipers are inserted as close to the edge of the nozzle opening as possible; readings are taken on three separate diameters and recorded. Each reading must agree within 0.1 mm (0.004 inch), or the nozzle must be reshaped. Any nozzle that has been nicked, dented, or corroded must be reshaped and recalibrated. All calibrated nozzles should be permanently identified.

Nozzle Number I-7

Marked nozzle size	-	Measured nozzle size	=	X	<= 0.004in
.502	-	.502	=	0	<= 0.004in
.502	-	.502	=	0	<= 0.004in
.502	-	.502	=	0	<= 0.004in

Job Number: 02-0301A
Done By / Date: TS / 5-9-02
Final Check By / Date: AW / 5-31-02

Ontario Hydro Probe Nozzle Inspection (3)

R-3

The probe nozzle should be made of 316 stainless steel or quartz with a sharp, tapered leading dge. A taper angle of less than or equal to 30 degrees on the outside of the sampling nozzle will preserve a constant internal diameter. The nozzle should be a button-hook or elbow design so that the nozzle opening is below the pitot tube sensing orifice. This is necessary for isokinetic sampling. Alternative construction materials or nozzle shapes must be approved by the administrator.

The sampling nozzle must be calibrated before use in a source experiment. Calibration should be done in the laboratory and checked just before use in the field. Inside / outside calipers are used to measure the interior nozzle diameter to the nearest 0.025mm (0.001 inch).

The calipers are inserted as close to the edge of the nozzle opening as possible; readings are taken on three separate diameters and recorded. Each reading must agree within 0.1 mm (0.004 inch), or the nozzle must be reshaped. Any nozzle that has been nicked, dented, or corroded must be reshaped and recalibrated. All calibrated nozzles should be permanently identified.

Nozzle Number 1-7

Marked nozzle size	-	Measured nozzle size	=	X	<= 0.004in
.522	-	.522	=	0	<= 0.004in
.522	-	.504	=	0.002	<= 0.004in
.502	-	.524	=	0.002	<= 0.004in
		x̄ .523			

Job Number: 020301A
Done By / Date: TS / 5-1-02
Final Check By / Date: AN / 5/3/02

Ontario Hydro Probe Nozzle Inspection

R-1

The probe nozzle should be made of 316 stainless steel or quartz with a sharp, tapered leading edge. A taper angle of less than or equal to 30 degrees on the outside of the sampling nozzle will preserve a constant internal diameter. The nozzle should be a button-hook or elbow design so that the nozzle opening is below the pitot tube sensing orifice. This is necessary for isokinetic sampling. Alternative construction materials or nozzle shapes must be approved by the administrator.

The sampling nozzle must be calibrated before use in a source experiment. Calibration should be done in the laboratory and checked just before use in the field. Inside / outside calipers are used to measure the interior nozzle diameter to the nearest 0.025mm (0.001 inch).

The calipers are inserted as close to the edge of the nozzle opening as possible; readings are taken on three separate diameters and recorded. Each reading must agree within 0.1 mm (0.004 inch), or the nozzle must be reshaped. Any nozzle that has been nicked, dented, or corroded must be reshaped and recalibrated. All calibrated nozzles should be permanently identified.

Nozzle Number 1-7

Marked nozzle size	-	Measured nozzle size	=	X	<= 0.004in
.502	-	.502	=	0	<= 0.004in
.502	-	.504	=	0.002	<= 0.004in
.502	-	.503	=	0.001	<= 0.004in
		= .503			

Job Number: 020301
Done By / Date: TS / 5-9-02
Final Check By / Date: A.W. / 5-9-02

Ontario Hydro Probe Nozzle Inspection (3)

R-2

The probe nozzle should be made of 316 stainless steel or quartz with a sharp, tapered leading ıge. A taper angle of less than or equal to 30 degrees on the outside of the sampling nozzle will preserve a constant internal diameter. The nozzle should be a button-hook or elbow design so that the nozzle opening is below the pitot tube sensing orifice. This is necessary for isokinetic sampling. Alternative construction materials or nozzle shapes must be approved by the administrator.

The sampling nozzle must be calibrated before use in a source experiment. Calibration should be done in the laboratory and checked just before use in the field. Inside / outside calipers are used to measure the interior nozzle diameter to the nearest 0.025mm (0.001 inch).

The calipers are inserted as close to the edge of the nozzle opening as possible; readings are taken on three separate diameters and recorded. Each reading must agree within 0.1 mm (0.004 inch), or the nozzle must be reshaped. Any nozzle that has been nicked, dented, or corroded must be reshaped and recalibrated. All calibrated nozzles should be permanently identified.

Nozzle Number L-5

Marked nozzle size	-	Measured nozzle size	=	X	<= 0.004in
.499	-	.498	=	0.001	<= 0.004in
.499	-	.499	=	0	<= 0.004in
.499	-	.499	=	0	<= 0.004in
		= .499			

Job Number: 020301
Done By / Date: TS / 5-9-02
Final Check By / Date: AW / 5-9-02

Air Compliance Testing, Inc.
(Ontario Hydro.xls-Probe Nozzle Inspection (3)) 3/8/2002

Ontario Hydro Probe Nozzle Inspection (4)

R-3

The probe nozzle should be made of 316 stainless steel or quartz with a sharp, tapered leading edge. A taper angle of less than or equal to 30 degrees on the outside of the sampling nozzle will preserve a constant internal diameter. The nozzle should be a button-hook or elbow design so that the nozzle opening is below the pitot tube sensing orifice. This is necessary for isokinetic sampling. Alternative construction materials or nozzle shapes must be approved by the administrator.

The sampling nozzle must be calibrated before use in a source experiment. Calibration should be done in the laboratory and checked just before use in the field. Inside / outside calipers are used to measure the interior nozzle diameter to the nearest 0.025mm (0.001 inch).

The calipers are inserted as close to the edge of the nozzle opening as possible; readings are taken on three separate diameters and recorded. Each reading must agree within 0.1 mm (0.004 inch), or the nozzle must be reshaped. Any nozzle that has been nicked, dented, or corroded must be reshaped and recalibrated. All calibrated nozzles should be permanently identified.

Nozzle Number L-7

Marked nozzle size	-	Measured nozzle size	=	X	
.502	-	.504	=	0.002	<= 0.004in
.502	-	.502	=	0	<= 0.004in
.502	-	.503	=	0.001	<= 0.004in
		≈ .503			

Air Compliance Testing, Inc.
(Ontario Hydro.xls-Probe Nozzle Inspection (4)) 3/8/2002

Job Number: 020301
Done By / Date: TS / 5-9-02
Final Check By / Date: AW / 5-9-02

Method 4 Pre-Test Meter Console (001) Calibration

Run No.	Calibration Meter Correction Factor (Yc)	Barometric Press. (Pb) (in.Hg)	Delta H (in w.g.)	Meter Box Volume (Vd) (cu.ft.)	Average Meter Box Temperature (Tm) (F)	Standard Meter Volume (Vc) (cu.ft.)	Standard Meter Temperature (Tc) (F)	Time (min.)	Gamma (Y)	Tolerance (plus or minus 0.02)	Delta H@	Tolerance (plus or minus 0.2)
1	1.003941817	28.42	1.000	6.786	69.33	6.791	64.83	12	1.0107	-0.000492	1.798	0.043
2	1.003941817	28.42	2.000	9.350	70.67	9.376	65.50	12	1.0114	0.000225	1.887	0.046
3	1.003941817	28.42	3.000	11.585	71.67	11.622	65.33	12	1.0114	0.000267	1.837	-0.003
										PASS		PASS
							Average		1.0112		1.841	

Pump Number T-PMP-008

Meter Box Number T-MTB-008

Reference Meter Number T-DGM-00[illegible]

Add Values to 30 Day Calibration History

Add Values to Dry Gas Meter Calibration History

Tag Meter Box

Job Number: [illegible]

Done By / Date: [illegible] / [illegible]-02

Checked By / Date: [illegible] / [illegible]

Final Check By / Date [illegible] / [illegible]

Air Compliance Testing, Inc.

Method 4 Pre-Test Dry Gas Meter/Orifice Calibration Data

Meter Box I.D: T - MTB - 008
Meter Box Serial Number: 0105085
Standard Meter I.D: T - DGM - 001
Temp Sensor I.D: T - THR - 006
Barometer I.D: T - BAR - 007
Leak Check: (+) ✓ (-)
Meter Box Level? yes

Standard Meter
Calibrated By: Apex Instruments
Calibration Date ~~June~~ April 19, 2000
Gamma: 1.003941817
Serial Number: 2299045

REMOVE CAPS FROM STANDARD METER

Run 1

Pressures
ΔH: 1 in.$H_2$0
Meter Box Vac: 5 in.Hg
P Bar: 28.42 **in.Hg**

Meter Readings

Begin	0	848.801	16.038
End	12	855.592	22.824
Net	12	6.791	6.786

(>5.0 dcf)

Temperatures

4	64	65	–	69
8	65	65	–	69
12	65	65	–	70
Avg.	64.70	65.0	–	–
Avg.	64.83		69.33	

Run 2

Pressures
ΔH: 2 in.$H_2$0
Meter Box Vac: 5 in.Hg
P Bar: 28.42 in.Hg

Meter Readings

	Time	Std Meter	Meter Box
Begin	0	856.186	23.417
End	12	865.562	32.767
Net	12	9.376	9.350

(>5.0 dcf)

Temperatures

Time (min)	Std Meter In	Std Meter Out	Meter Box In	Meter Box Out
4	65	66	–	70
8	65	66	–	71
12	65	66	–	71
Avg.	65.0	66.0	–	–
Avg.	65.50		70.67	

Run 3

Pressures
ΔH: 3 in.$H_2$0
Meter Box Vac: 5 in.Hg
P Bar: 28.42 in.Hg

Meter Readings

	Time	Std Meter	Meter Box
Begin	0	866.265	33.478
End	12	877.887	45.063
Net	12	11.622	11.585

(>5.0 dcf)

Temperatures

Time (min)	Std Meter In	Std Meter Out	Meter Box In	Meter Box Out
4	65	65	–	71
8	65	66	–	72
12	65	66	–	72
Avg.	65.0	65.7	–	–
Avg.	65.33		71.67	

ΔH:	$\Delta H_@$	Y
1	1.798	1.0107
2	1.857	1.0114
3	1.837	1.0114
AVG	1.8407	1.0112

*Adjust and recalculate if Y does not equal 1.00 ± 0.02

Job Number 020502
Done By / Date MS / 5-2-02
Checked By / Date [illegible] / 5-3-02 [illegible] / 5-3-02
Final Check By / Date [illegible] / 5-3-02

Air Compliance Testing, Inc.
(method 4 Pre-Test Dry Gas Meter) 4/6/01

Method 4 Meter Box Pre-Test Leak Check

- ✓ Remove the front panel from the meter box
- ✓ Disconnect the fan
- ✓ Hook up the proper pump to the meter box
- ✓ Close both the fine and coarse adjustment valves
- ✓ Connect the DH hoses on the front of the meter box
- ✓ Remove the copper elbow from stainless tube at the exit side of gas meter
- ✓ Stopper the stainless tube with a rubber stopper
- ✓ Disconnect the DH static line from the orifice (bottom)
- ✓ Plug in leak check tube into the static side of the orifice
- ✓ Blowing into the leak check tube, pressurize the system to 5-7 inches and clamp off
- ✓ Hold for one minute
- ✓ No leakage should occur. If leak is present, it must be corrected
- ✓ Reassemble meter box
- ✓ Plug in capped swagelok stem at sample inlet
- ✓ Start pump, bringing system vacuum to at least 15 in. Hg
- ✓ Note DGM reading, start timer
- ✓ Observe DGM for one minute
- ✓ No leakage should occur. If leak is present, it must be corrected

Meter Box Number T-MTB-008

Method 4 Pre-Test Meter Console (001) Calibration

Run No.	Calibration Meter Correction Factor (Yc)	Barometric Press. (Pb) (in.Hg)	Delta H (in w.g.)	Meter Box Volume (Vd) (cu.ft.)	Average Meter Box Temperature (Tm) (F)	Standard Meter Volume (Vc) (cu.ft.)	Standard Meter Temperature (Tc) (F)	Time (min.)	Gamma (Y)	Tolerance (plus or minus 0.02)	Delta H@	Tolerance (plus or minus 0.2)
1	1.003941817	28.81	1.000	7.248	67.00	6.800	62.83	12	**0.9470**	-0.006968	1.763	0.027
2	1.003941817	28.81	2.000	11.096	73.67	10.418	64.17	13	**0.9548**	0.000862	1.750	0.014
3	1.003941817	28.77	3.000	12.711	78.17	11.964	65.67	12	**0.9601**	0.006106	1.694	-0.042
										PASS		PASS
							Average		**0.9539**		1.736	

Pump Number T-PMP- 010

Meter Box Number T-MTB- 010

Reference Meter Number T-DGM- 001

Add Values to 30 Day Calibration History

Add Values to Dry Gas Meter Calibration History

Tag Meter Box. Recalibrate

Job Number: 020501

Done By / Date: [illegible] / 5-1-02

Checked By / Date: [illegible] / 5-1-02

Final Check By / Date: [illegible]

Air Compliance Testing, Inc.

Method 4 Pre-Test Dry Gas Meter/Orifice Calibration Data

Meter Box I.D: T - MTB - 00C
Meter Box Serial Number: 4/01
Standard Meter I.D: T - DGM - 001
Temp Sensor I.D: T - THR - 006
Barometer I.D: T - BAR - 004
Leak Check: (+) ✓ (-)
Meter Box Level? yes

Standard Meter
Calibrated By Apex Instruments
Calibration Date ~~June~~ Jan 19, 2000
Gamma: 1.003941817
Serial Number: 2299045

REMOVE CAPS FROM STANDARD METER

Run 1

Pressures
ΔH: 1 **in.H_20**
Meter Box Vac: 5 in.Hg
P Bar: 28.81 **in.Hg**

Meter Readings

	Time	Std Meter	Meter Box
Begin	0	710.198	104.252
End	12	716.998	111.500
Net	12	6.800	7.248

(>5.0 dcf)

Temperatures

Time (min)	Std Meter In	Std Meter Out	Meter Box In	Meter Box Out
4	62	63	67	63
8	63	63	70	64
12	63	63	74	64
Avg.	62.7	63.0	70.33	63.7
Avg.	62.83		67.00	

Run 2

Pressures
ΔH: 2 **in.H_20**
Meter Box Vac: 5 in.Hg
P Bar: 28.81 **in.Hg**

Meter Readings

	Time	Std Meter	Meter Box
Begin	0	719.167	113.792
End	13	729.585	124.888
Net	13	10.418	11.096

(>5.0 dcf)

Temperatures

Time (min)	Std Meter In	Std Meter Out	Meter Box In	Meter Box Out
4	64	64	79	66
8	64	64	81	66
12	64	65	83	67
Avg.	64.0	64.3	81.0	66.3
Avg.	64.17		73.67	

Run 3

Pressures
ΔH: 3 in.H_20
Meter Box Vac: 5 in.Hg
P Bar: 28.77 in.Hg

Meter Readings

	Time	Std Meter	Meter Box
Begin	0	731.134	126.538
End	12	743.098	139.249
Net	12	11.964	12.711

(>5.0 dcf)

Temperatures

Time (min)	Std Meter In	Std Meter Out	Meter Box In	Meter Box Out
4	66	65	84	69
8	65	65	87	70
12	67	66	88	71
Avg.	66	65.33	86.33	70.
Avg.	65.66		78.17	

ΔH:	$\Delta H_@$	Y
1	1.763	0.9470
2	1.750	0.9545
3	1.694	0.9601
AVG	1.7354	0.9534

* Adjust and recalculate if Y does not equal 1.00 ± 0.02

Job Number 02C501
Done By / Date MJ / 5-1-02
Checked By / Date [illegible] / [illegible] KJ / 5-3-02
Final Check By / Date APL / 5-3-02

Air Compliance Testing, Inc.
(method 4-Pre-Test Dry Gas Meter) 4/8/01

Method 4 Meter Box Pre-Test Leak Check

- Remove the front panel from the meter box
- ✓ Disconnect the fan
- ✓ Hook up the proper pump to the meter box
- ✓ Close both the fine and coarse adjustment valves
- ✓ Connect the DH hoses on the front of the meter box
- ✓ Remove the copper elbow from stainless tube at the exit side of gas meter
- ✓ Stopper the stainless tube with a rubber stopper
- ✓ Disconnect the DH static line from the orifice (bottom)
- ✓ Plug in leak check tube into the static side of the orifice
- ✓ Blowing into the leak check tube, pressurize the system to 5-7 inches and clamp off
- ✓ Hold for one minute
- ✓ No leakage should occur. If leak is present, it must be corrected
- ✓ Reassemble meter box
- ✓ Plug in capped swagelok stem at sample inlet
- ✓ Start pump, bringing system vacuum to at least 15 in. Hg
- ✓ Note DGM reading, start timer
- ✓ Observe DGM for one minute
- ✓ No leakage should occur. If leak is present, it must be corrected

Meter Box Number T-MTB-010

Job Number C7 0501
Done By [illegible] Date [illegible]

Method 4 DGM Calibration History

Type	Date	Standard Meter Serial #	Meter Box #	Delta H	Delta H@	Delta H	Delta H@	Delta H	Delta H@	Gamma	Average Delta H@	By
Pre	3-4-02	27028	010	1	1.796	2	[illegible]	3	1.743	0.9885	1.782	D[illegible]
Pre	3-8-02	27028	008	1	1.735	2	1.79[illegible]	3	1.785	0.9814	1.761	DV
PRE	3.27.02	27028	008	1	1.794	2	1.827	3	1.740	0.9780	1.787	JG
PRE	3.28.02	27028	003	1	1.667	2	1.736	3	1.664	1.0183	1.689	JG
PRE	4.02.02	27028	009	1	1.748	2	1.760	3	1.754	1.0157	1.754	[illegible]
PRE	4.02.02	27028	007	1	2.005	2	2.075	3	2.063	1.0035	2.047	[illegible]
PRE	4.2.02	27028	006	1	1.609	2	1.647	3	1.619	0.9610	1.625	JG
Pre	4-8-02	27028	010	1	1.584	2	1.608	3	1.571	0.9958	1.588	[illegible]
~~PRE~~	~~4-9-02~~	~~27028~~	~~011~~	~~1~~	~~1.671~~	~~2~~	~~1.691~~	~~3~~	~~1.643~~	~~1.0161~~	~~1.0213~~	~~[illegible]~~
PRE	4-9-02	27028	011	1	1.671	2	1.691	3	1.643	1.0190	1.668	[illegible]
PRE	4-16-02	27028	003	1	1.617	2	1.621	3	1.586	1.0267	1.608	[illegible]
PRE	3-21-02	27028	004	1	2.091	2	2.188	3	2.165	1.0050	2.148	AG
PRE	4-18-02	27028	004	1	1.979	2	2.077	3	2.124	1.0049	2.060	AG
Pre	4-26-02	2299045	011	1	1.594	2	1.619	3	1.599	.9982	1.604	MS
Post	4-26-02	27028	011	.996	1.693	.996	1.685	.996	1.698	1.0108	1.692	MS
Pre	4-23-02	27028	008	1	1.766	2	1.855	3	1.788	.9774	1.803	KO
Pre	5-1-02	2299045	006	1	1.835	2	1.896	3	1.864	.9880	1.865	MS
Pre	5-1-02	2299045	009	1	1.831	2	1.825	3	1.778	.9800	1.8114	MS
Pre	5-1-02	2299045	010	1	1.763	2	1.750	3	1.694	.9539	1.7359	MS
Pre	5-2-02	2299045	010	1	1.764	2	1.768	3	1.702	1.0096	1.745	MS
Pre	5-2-02	2299045	008	1	1.798	2	1.882	3	1.837	1.0117	1.8407	MS
Pre	5-2-02	2299045	004	1	2.208	2	2.289	3	2.282	.9703	2.2598	MS
~~Pre~~	~~4-18-02~~	~~27028~~	~~004~~	~~1.0~~	~~1.979~~	~~2.0~~	~~2.077~~	~~3~~	~~2.124~~	~~1.0049~~	~~2.060~~	~~AG~~
Pre	4-11-02	41161	010	1.0	1.524	2.0	1.626	3	1.577	0.9900	1.576	AG
Pre	5-3-02	2299045	003	1	1.567	2	1.594	3	1.561	1.9968	1.5739	MS
Pre	5-6-02	2299045	002	1	2.103	2	2.201	3	2.152	0.9701	2.1534	MS
Pre	5-29-02	2299045	006	1	1.888	2	2.028	3	1.984	.9753	1.9669	DV
Pre	5-29-02	2299045	008	1	1.961	2	1.998	3	1.938	1.0040	1.9659	DV
Pre	6-[illegible]-02	2299045	010	1	1.755	2	1.780	3	[illegible]741	1.0044	1.765	MS
Pre	6-[illegible]-02	[illegible]	011	1	[illegible]2	2	[illegible]	3	[illegible]7	[illegible]	1.6[illegible]9	[illegible]

Air Compliance Testing, Inc.

APEX INSTRUMENTS REFERENCE METER VERIFICATION
USING WET-TEST METER #11AE6
2-POINT ENGLISH UNITS

Calibration Meter Information	
Wet Test Meter Model #	AL20
Wet Test Meter Serial #	11AE[illegible]
Wet Test Meter Gamma	1.00000

Calibration Conditions			
Date	Time	19-Apr-02	15:00
Barometric Pressure		29.60	in Hg
Calibration Technician		QMD	
DGM Serial Number		2299045	

Factors/Conversions		
Std Temp	528	[illegible]
Std Press	29.92	[illegible]
K_1	17.647	[illegible]

Run Time	Metering Console					Calibration Meter				Results		
										Dry Gas Meter		
										Calibration Factor		Flowrate
Elapsed	DGM Input Pressure	Volume Initial	Volume Final	Outlet Temp Initial	Outlet Temp Final	Volume Initial	Volume Final	Outlet Temp Initial	Outlet Temp Final	Previous	Current	Std & Corr
[illegible]	[illegible]	(V_{mi})	(V_{mf})	(t_{mi})	(t_{mf})	(Vw_i)	(Vw_f)	(t_{wi})	(t_{wf})	(Y)	[illegible]	
[illegible]	[illegible]	cubic feet	cubic feet	°F	°F	cubic feet	cubic feet	°F	°F			[illegible]
[illegible]	1.0	541.705	548.719	83	83	21.179	27.979	77	77	1.005	0.990[illegible]	0.945
									Variation	1.43%	must be less than 1.5%	
25.00	2.3	548.719	558.256	83	83	27.979	37.493	77	77	1.010	1.0145	0.570
									Variation	0.47%	must be less than 1.5%	

[illegible] that the above Dry Gas Meter was calibrated in accordance with USEPA Methods, CFR 40 Part 60, App A, Method 5, Paragraph 7.1.2.2, using the Precision Wet Test Meter # 11AE6, [illegible] was calibrated using the American Bell Prover # 3785, certificate # F107, which is traceable to the National Bureau of Standards (N.I.S.T.).

Signature Quentin M. Dart Date 4/19/02

REFERENCE METER CALIBRATION
ENGLISH REFERENCE METER UNITS

DGM Serial # 2299045
Date 06/19/00

Barometric Pressure 29.60
Meter Yw 1.00000
K (deg R/inches Hg) 17.64

Filename: F:\DATAFILE\CALIBRAT\CAL_MENU.DSK\DGM REF [illegible]
Revised: 06/08/95

Time (min)	Pressure (in H2O)	Dry Gas Meter (DGM) Meter Readings Initial	Final	Volume (cubic feet)	Temperature Initial (deg F)	Final (deg F)	Wet Test Meter (WTM) Meter Readings Initial	Final	Volume (cubic feet)	Temp (deg F)	DGM Coefficient Yds	Coefficient Variation Yds-(Avg.Yds)	Flow Rate (CFM)
[illegible]	8.100	294.918	302.356	7.438	81.0	81.0	754.810	762.000	7.190	79.0	0.990	-0.004	1.266
[illegible]	8.200	302.356	308.597	6.241	80.0	78.0	762.000	768.080	6.080	79.0	0.994	0.000	[illegible]
[illegible]	8.200	308.597	318.329	9.732	78.0	78.0	768.080	777.610	9.530	79.0	0.998	0.004	[illegible]
									Max Yds - Min Yds =		0.007582821	Must be no greater than 0.030	
									Average Yds =		0.994126118	Must be between 0.95 to 1.05	
52.50	5.000	318.329	371.068	52.739	78.0	79.0	777.610	830.445	52.835	79.0	1.013	0.009	[illegible]
10.00	5.000	371.068	381.164	10.096	79.0	79.0	830.445	840.420	9.975	79.0	1.000	-0.004	0.966
[illegible]	5.000	381.161	397.368	16.204	79.0	80.0	840.420	856.405	15.985	79.0	1.000	-0.005	0.968
									Max Yds - Min Yds =		0.0136607	Must be no greater than 0.030	
									Average Yds =		1.004579364	Must be between 0.95 to 1.05	
[illegible]	3.600	397.368	411.985	14.617	80.0	80.0	856.405	870.950	14.545	79.0	1.006	0.002	[illegible]
[illegible]	3.600	411.985	430.263	18.278	80.0	80.0	870.950	889.095	18.145	79.0	1.004	0.000	0.781
[illegible]	3.600	430.263	479.058	48.795	80.0	80.0	889.095	937.459	48.364	79.0	1.002	0.002	0.781
									Max Yds - Min Yds =		0.003949671	Must be no greater than 0.030	
									Average Yds =		1.003807377	Must be between 0.95 to 1.05	
[illegible]	2.100	479.058	499.947	20.889	80.0	81.0	937.459	958.350	20.891	79.0	1.009	0.002	[illegible]
[illegible]	2.100	499.947	509.696	9.749	81.0	81.0	958.350	968.078	9.728	79.0	1.008	0.000	[illegible]
[illegible]	2.100	509.696	535.570	25.874	81.0	82.0	968.078	993.821	25.743	79.0	1.006	-0.002	0.554
									Max Yds - Min Yds =		0.003347159	Must be no greater than 0.030	
									Average Yds =		1.007331955	Must be between 0.95 to 1.05	
[illegible]	1.400	535.570	542.130	6.560	82.0	82.0	993.821	1000.400	6.579	79.0	1.012	0.002	0.335
[illegible]	1.400	542.130	551.186	9.056	82.0	82.0	1000.400	1009.450	9.050	79.0	1.008	-0.001	[illegible]
[illegible]	1.400	551.186	560.096	8.910	82.0	82.0	1009.450	1018.361	8.911	79.0	1.009	0.001	[illegible]
									Max Yds - Min Yds =		0.003591183	Must be no greater than 0.030	
									Average Yds =		1.009864273	Must be between 0.95 to 1.05	

Overall Average Yds = 1.003941817

I certify that the above Dry Gas Meter was calibrated in accordance with E.P.A. Method 5, paragraph 7.1 ;CFR 40 Part 60, using the Precision Wet Test Meter # 11AE6, which in turn was calibrated using the American Bell Prover # 3785, certificate # 1197, which is traceable to the National Bureau of Standards (N.I.S.T.).

Signature ______________ Date 6-19-00

Pallflex® Filters

Description: Wide range of filters uniquely suited for a broad range of air monitoring applications
Can be used for high temperature and hot gas air monitoring applications.

Specifications

Description	Tissuquartz Filters	Emfab Filters	Fiberfilm Filtes
Filter Media	Pure quartz, no binder	Borosilicate microfibers reinforced with woven glass cloth and bonded with PTFE	Heat resistant borosilicate glass fiber coated with fluorocarbon (TFE)
Diameter	25 - 90 mm (and 8 x 10 in.)	12 - 142 mm (and 8 x 10 in.)	25 - 100 mm (and 8 x 10 in.)
Typical Thickness	432 μm (17 mils)	178 μm (7 mils)	203 μm (8 mils)
Typical Filter Weight	5.8 mg/cm^2	5.0 mg/cm^2	3.4 mg/cm^2
Typical Water Flow Rate at 0.35 bar (5 psi)	220 $mL/min/cm^2$	32 $mL/min/cm^2$	220 $mL/min/cm^2$
Typical Air Flow Rate at 0.7 bar (10 psi)	73 $L/min/cm^2$	68 $L/min/cm^2$	180 $L/min/cm^2$
Maximum Operating Temperature - Air	1093 °C (2000 °F)	260 °C (500 °F)	315.5 °C (600 °F)
Typical Aerosol Retention*	99.90%	99.90%	96.40%
pH in Boiled Water Extract	6.5 - 7.5	Not available	Not available

Following ASTM D 2986-71 0.3 um (DOP) at 32 L/min/100 cm^2 filter media

OMEGA INC.
An OMEGA Technologies Company

Certificate of Calibration

Customer:	Air Compliance Testing
Customer P.O.:	011099
Instrument:	**Omega CL23A**
Work Order Number:	**110989588**
Description:	**Digital Calibrator Thermometer**
Serial Number:	**T-229854**
Equipment I.D.#:	**110989588**
A.R. Number:	

Cal-3

Omega Engineering, Inc. hereby certifies that...
the above instrumentation has been calibrated and tested to **meet or exceed** the published specifications. This calibration and testing was performed using instrumentation and standards that are traceable to the **National Institute of Standards and Technology**. Omega Engineering, Inc. is in compliance with ISO 10012-1, ISO 9001 Section 4.11 and ANSI/NCSL Z540-1-1994. This certificate shall not be reproduced, except in full, without the written consent of Omega Engineering, Inc.

CALIBRATION INFORMATION

Cal Date: 24-Oct-01
Cal Due Date: 24-Oct-02
Temperature: 22.0°C
Humidity: 61 %
NIST Traceable Numbers: 775585-5985307, OM-10719206, 4401T794301
Absolute Uncertainty: 0.19 F, 9ppm Rdg + 3ppm Rng mVDC
Comments:

Pass Y **Technician:** Robert Schaale
Procedure: QAP-2100
Seals OK Yes
Certificate #: 012218

STANDARDS USED FOR CALIBRATION

Asset Number	Mfg	Model	Description	Cal. Date	Due Date
01203	Fluke	5700A	Multicalibrator	14-Sep-01	13-Sep-02
01154	Omega	TRCIII	Ice Point	24-Oct-01	31-Oct-01
01505	Hewlett Packard	HP3458A	Digital Multimeter	15-May-01	15-May-02

Metrology Technician:

Quality Assurance Inspector:

File rcert01.rpt

Barometer Calibration History

Aneroid Barometer #	("Hg) Mercury Barometer	("Hg) Aneroid Barometer	("Hg) Difference	[illegible]	By whom	Date	Adjusted?	(°F) Temp.
[illegible]	28.79	[illegible]	[illegible]	[illegible]	JG	3.26.02	No	[illegible]
T-BAR-003	28.85	28.76	-.09	[illegible]	AG	3.26.02	Yes	[illegible]
T-BAR-004	~~28.82~~ 28.85	28.82	-.03	Pass	AG	3.26.02	No	68
T-BAR-005	29.23	29.21	.02	PASS	CS/SH	3-27-02	NO	68
T-BAR-004	29.23	29.34	.11	FAIL	CS/SH	3.27.02	YES	68
T-BAR-003	29.23	29.44	.21	FAIL	SHC	32702	YES	68
~~T-BAR-003~~	~~29.38~~	~~29.05~~	~~0.33~~	~~FAIL~~	~~SHC~~	~~32802~~	~~YES~~	
T-BAR-003	29.08	29.05	0.03	PASS	SHC	3 28 02	NO	68
T-BAR-005	29.08	29.07	0.01	PASS	SHC	3 28 02	NO	68
T-BAR-004	29.08	29.05	0.03	PASS	SHC	3 28 02	NO	68
T-BAR-001	29.29	~~.35~~ 29.30	0.01	Pass	JG	4.11.02	NO	71
T-BAR-003	~~29.28~~ 29.27	29.27	0.00	Pass	JG	4.11.02	NO	72
T-BAR-005	29.29	29.30	0.01	Pass	JG	4.11.02	No	71
T-BAR-004	29.29	29.30	0.01	Pass	JG	4.11.02	No	71
T-BAR-005	29.15 SHC	29.12	0.03	PASS	SHC	4.16.02	NO	76
T-BAR-005	29.28	29.24	0.04	PASS	SHC	4.26.02	NO	68
T-BAR-001	29.~~30~~ 28 SHC	29.30	0.02	PASS	SHC	4.26.02	No	68
T-BAR-003	28.98	28.82	0.16	Fail	CS	4-29-02	YES	68
T-BAR-005	28.98	28.96	0.02	PASS	CS	4-29-02	NO	68
T-BAR-004	28.98	28.90	0.08	PASS	CS	4-29-02	NO	68
T-BAR-005	28.95	28.89	0.06	Pass	JH-AG	5-1-02	NO	68
T-BAR-003	28.95	28.96	0.01	Pass	JH-AG	5-1-02	NO	68
T-BAR-001	29.15	29.16	0.01	Pass	JG	5.3.02	No	66
T-BAR-005	29.15	29.08	-0.07	Pass	JG	5.3.02	Yes	66
T-BAR-003	28.73	28.75	0.02	Pass	JG	5.9.02	No	71
T-BAR-003	29.115	29.12	0.005	PASS	SHC	5.17.02	NO	SHC ~~68~~ 69
T-BAR-001	29.115	29.10	0.015	PASS	SHC	5.17.02	NO	~~68~~ SHC 69
T-BAR-001	29.1328	29.15	-0.0172	Pass	APG	6.10.02	No	76
T-BAR-003	29.1328	29.18	-0.0472	Pass	APG	6.10.02	No	76
T-BAR-005	29.1328	29.17	-0.0372	Pass	APG	6.10.02	No	76
T-BAR-004	29.1328	29.09	0.0428	Pass	APG	6.10.02	No	76

LAKE BALANCE COMPANY, INC.

P.O. BOX 215 • MADISON, OHIO 44057-0215 • (440) 428-3993 • 1-800-334-6756 • FAX (440) 428-2662

SERVICE AND CALIBRATION REPORT

CUSTOMER	BILLING ADDRESS	PURCHASE ORDER NO.
Aitz Comp N. Royalton		SERVICE REP. MARK KUSICK CAL DATE 12-28-01 DUE DATE 1-30-03 CODE

Department	Building	Room	Individual	
				PAGE 3 OF 5

Instrument A-BAL-004	8.0	8.4		Warranty hrs. ea
Mfr: AED	Cal. Wt. 1000G			Install. hrs. ea.
Model No: EK1200G	Scale 1200G			Recall hrs. ea.
Serial No: 58084809	Grads. 0.1G			Emg. hrs. ea.

AS FOUND STATUS	REASON FOR SERVICE	
☒ In Tolerance	☒ Scheduled	Travel hrs. ea.
☐ Out of Tolerance	☐ Unscheduled	Bench hrs. ea.
☐ Inoperative		Sales Tax Ex. No.

UNITS	AS FOUND TEST DATA		FINAL TEST DATA		CHECK LIST
	Instrument	Tolerance ±	Test 1	Test 2	
0	0.0	0.3G	0.0	.0.0	LEVEL ☑
100 G	100.0G	↓	100.0 G	100.0G	
600 G	599.8G	↓	600.0G	600.0 G	CORNERLOAD ☑
1200 G	1199.7G	↓	1200.0G	1200.0G	
					LINEARITY ☑

Comments

Standards Used	N.I.S.T. Number	Serial Number	Class	Due Date
5Kg Wt Set	0335	9120	1	4-30-02

Part No.	Description	Quantity	Price Ea.

FINAL STATUS
✓CALIBRATED
VERIFICATION
LIMITED CAL.
DO NOT USE

SOP
2AP12
Test
2FWI 0F
Standard
MFR

Customer Date

FORM 0100-01 ORIGINAL COPY CUSTOMER YELLOW AND PINK COPY BUSINESS

6/17/02

Review of ACT Report on Hg measurement at Burger ECO pilot

(1) Page 4 - what does the statement "In order to obtain positive values, the particle bound and oxidized ~~fractions~~ mercury fractions of the ECO Process Exhaust Duct were not blank corrected" mean?

(2) Table 2.2 - Emissions Results, Page 7
- The reported inlet and outlet acfm do not look to be correct. Did the reported flow rate change on the DAQ?

- Check the H_2O measurements recorded by the DAQ for the times listed in the report.

- Check the CO_2 measurements recorded by the DAQ.

(3) If we move either set of sample points to allow continuous sampling, the outlet port locations should be moved.

(4) Page 11, Section 4.1.5 Ontario Hydro Method: last sentence says, that method is applicable to elemental, oxidized, particle-bound and total mercury concentrations ranging from approximately 0.5 ~~to~~ 100 µg/dscm. Many of our concentrations reported in Table 2.2 are below 0.5 µg/dscm

(5) Check with Keith about ΔP values we can measure. ACT measured values of 0.012 to 0.002 "wc

(6) Analytical lab report date is 5/20 - why has it taken another month to get the results?

Inlet Run 2

Date/Time	Chan	Result	loading	Elem Hg	Total Hg	BS Elem Hg	BS Total Hg
7:52	3	196.65	0.20	0.20		0.12	
8:04	3	201.20	0.20	0.20		0.12	
8:16	3	139.52	0.14	0.14		0.06	
8:28	3	112.13	0.11	0.11		0.03	
8:41	3	134.02	0.13	0.13		0.05	
8:53	3	125.83	0.13	0.13		0.05	
9:05	3	119.00	0.12	0.12		0.04	
9:18	3	113.48	0.11	0.11		0.03	
9:30	3	127.20	0.13	0.13		0.05	
9:42	3	142.30	0.14	0.14		0.06	
9:54	3	160.11	0.16	0.16		0.08	
10:07	3	173.81	0.17	0.17		0.09	
10:19	3	134.06	0.13	0.13		0.05	
10:31	3	162.84	0.16	0.16		0.08	
10:43	3	133.97	0.13	0.13		0.05	
10:56	3	127.04	0.13	0.13		0.05	
11:08	3	114.42	0.11	0.11		0.03	
11:22	3	100.93	0.10	0.10		0.02	
11:34	3	119.67	0.12	0.12		0.04	
11:46	3	138.66	0.14	0.14		0.06	
11:59	3	156.78	0.16	0.16		0.08	
7:44	4	6805.49	6.81		6.81		6.50
7:56	4	5161.41	5.16		5.16		4.86
8:09	4	5153.30	5.15		5.15		4.85
8:21	4	4140.71	4.14		4.14		3.84
8:33	4	3995.31	4.00		4.00		3.69
8:46	4	3413.36	3.41		3.41		3.11
8:58	4	4319.17	4.32		4.32		4.02
9:10	4	4505.90	4.51		4.51		4.20
9:22	4	4881.82	4.88		4.88		4.58
9:35	4	5268.93	5.27		5.27		4.97
9:47	4	5159.02	5.16		5.16		4.86
9:59	4	5949.47	5.95		5.95		5.65
10:11	4	5858.93	5.86		5.86		5.56
10:24	4	5754.55	5.75		5.75		5.45
10:36	4	4722.63	4.72		4.72		4.42
10:48	4	5537.54	5.54		5.54		5.24
11:00	4	4836.50	4.84		4.84		4.54
11:13	4	4454.64	4.45		4.45		4.15
11:27	4	5601.83	5.60		5.60		5.30
11:39	4	4852.61	4.85		4.85		4.55
11:51	4	5428.32	5.43		5.43		5.13

Total Blanks	Elem Blanks
0.34	0.08
0.31	0.08
0.30	0.08
0.30	0.08
0.28	
0.28	

avg tot blank	avg elem blank
0.30	0.08

avg BS Elem Hg		std BD Elem Hg	
0.06	ug / m3	0.03	ug / m3
avg BS Tot Hg		std BS Tot Hg	
4.74	ug / m3	0.77	ug / m3

[redacted]

Inlet Run 3

Date/Time	Chan	Result	loading	Elem Hg	Total Hg	BS Elem Hg	BS Total Hg
12:23	3	526.68	0.53	0.53		0.45	
12:35	3	367.41	0.37	0.37		0.29	
12:47	3	296.53	0.30	0.30		0.22	
12:59	3	279.53	0.28	0.28		0.20	
13:12	3	245.22	0.25	0.25		0.17	
13:24	3	253.77	0.25	0.25		0.17	
13:36	3	261.69	0.26	0.26		0.18	
13:49	3	253.44	0.25	0.25		0.17	
14:01	3	257.67	0.26	0.26		0.18	
14:13	3	267.25	0.27	0.27		0.19	
14:25	3	278.18	0.28	0.28		0.20	
14:38	3	219.17	0.22	0.22		0.14	
14:50	3	177.95	0.18	0.18		0.10	
15:02	3	209.48	0.21	0.21		0.13	
15:14	3	217.76	0.22	0.22		0.14	
15:27	3	231.60	0.23	0.23		0.15	
15:39	3	239.74	0.24	0.24		0.16	
15:51	3	246.58	0.25	0.25		0.17	
16:04	3	254.82	0.25	0.25		0.17	
16:16	3	256.03	0.26	0.26		0.18	
16:28	3	267.09	0.27	0.27		0.19	
12:15	4	9283.37	9.28		9.28		8.98
12:27	4	5461.17	5.46		5.46		5.16
12:40	4	5549.24	5.55		5.55		5.25
12:52	4	5631.34	5.63		5.63		5.33
13:04	4	5996.19	6.00		6.00		5.70
13:17	4	5891.84	5.89		5.89		5.59
13:29	4	5894.67	5.89		5.89		5.59
13:41	4	5793.00	5.79		5.79		5.49
13:53	4	5710.93	5.71		5.71		5.41
14:06	4	5823.13	5.82		5.82		5.52
14:18	4	7321.78	7.32		7.32		7.02
14:30	4	6586.16	6.59		6.59		6.29
14:42	4	5979.69	5.98		5.98		5.68
14:55	4	6498.34	6.50		6.50		6.20
15:07	4	6374.65	6.37		6.37		6.07
15:19	4	6108.63	6.11		6.11		5.81
15:31	4	5974.00	5.97		5.97		5.67
15:44	4	6103.14	6.10		6.10		5.80
15:56	4	6336.40	6.34		6.34		6.04
16:08	4	6199.47	6.20		6.20		5.90
16:21	4	6385.72	6.39		6.39		6.08
16:33	4	6105.74	6.11		6.11		5.80

Total Blanks	Elem Blanks
0.38	0.08
0.34	0.08
0.31	0.08
0.30	0.08
0.30	0.08
0.28	
0.28	
avg tot blank	avg elem blank
0.30	0.08

avg BS Elem Hg		std BS Elem Hg	
0.19	ug / m3	0.07	ug / m3
avg BS Tot Hg		std BS Tot Hg	
5.93	ug / m3	0.79	ug / m3

[redacted]

ACT - 5/8 1849 to 21:55

Port Tin changes 19:56
20:55

Inlet Run 1

Date/Time	Chan	Result	loading	Elem Hg	Total Hg	BS Elem Hg	BS Total Hg
18:41	3	720.14	0.72	0.72		0.64	
18:54	3	711.85	0.71	0.71		0.63	
19:06	3	726.94	0.73	0.73		0.64	
19:18	3	709.60	0.71	0.71		0.63	
19:30	3	702.21	0.70	0.70		0.62	
19:43	3	674.74	0.67	0.67		0.59	
19:55	3	651.39	0.65	0.65		0.57	
20:07	3	644.62	0.64	0.64		0.56	
20:19	3	615.80	0.62	0.62		0.53	
20:32	3	610.27	0.61	0.61		0.53	
20:44	3	596.53	0.60	0.60		0.51	
20:56	3	585.54	0.59	0.59		0.50	
21:09	3	604.73	0.60	0.60		0.52	
21:21	3	555.35	0.56	0.56		0.47	
21:33	3	361.88	0.36	0.36		0.28	
21:45	3	488.13	0.49	0.49		0.40	
21:58	3	479.88	0.48	0.48		0.40	
18:46	4	4078.42	4.08		4.08		3.78
18:58	4	4766.54	4.77		4.77		4.47
19:11	4	5043.78	5.04		5.04		4.74
19:23	4	5058.64	5.06		5.06		4.76
19:35	4	4961.98	4.96		4.96		4.66
19:47	4	5120.66	5.12		5.12		4.82
20:00	4	3836.33	3.84		3.84		3.54
20:12	4	5093.60	5.09		5.09		4.79
20:24	4	4997.09	5.00		5.00		4.70
20:37	4	4914.78	4.91		4.91		4.61
20:49	4	5277.10	5.28		5.28		4.98
21:01	4	2905.67	2.91		2.91		2.60
21:13	4	4497.84	4.50		4.50		4.20
21:26	4	5117.94	5.12		5.12		4.82
21:38	4	4761.03	4.76		4.76		4.46
21:50	4	5381.31	5.38		5.38		5.08
22:02	4	5633.72	5.63		5.63		5.33
17:23	13	81.91	0.08				
17:30	13	84.80	0.08				
17:36	13	81.61	0.08				
17:43	13	84.56	0.08				
17:49	13	84.95	0.08				
17:56	13	81.88	0.08				
16:25	15	1250.66	1.25				
16:31	15	449.48	0.45				
16:38	15	381.70	0.38				
16:44	15	335.54	0.34				
16:51	15	310.99	0.31				
16:57	15	302.13	0.30				
17:04	15	296.70	0.30				
17:10	15	284.71	0.28				
17:17	15	276.63	0.28				

Total Blanks	Elem Blanks
0.38	0.08
0.34	0.08
0.31	0.08
0.30	0.08
0.30	0.08
0.28	
0.28	

avg tot blank	avg elem blank
0.30	0.08

avg BS Elem Hg		std BS Elem Hg	
0.53	ug / m3	0.10	ug / m3
avg BS Tot Hg		std BS Tot Hg	
4.49	ug / m3	0.56	ug / m3

[redacted]

Outlet Run 1

Date/Time	Chan	Result	loading	Elem Hg	Total Hg	BS Elem Hg	BS Total Hg	Total Blanks	Elem Blanks
8:41	1	775.34	0.78	0.78		0.77		0.13	0.03
8:51	1	749.78	0.75	0.75		0.74		0.12	0.02
9:00	1	763.40	0.76	0.76		0.76		0.12	0.01
9:10	1	669.89	0.67	0.67		0.66		0.13	0.01
9:20	1	682.95	0.68	0.68		0.68		0.13	0.01
9:29	1	650.42	0.65	0.65		0.64		0.13	0.01
9:41	1	607.27	0.61	0.61		0.60		0.11	0.00
9:50	1	564.40	0.56	0.56		0.56		0.02	-0.04
10:00	1	573.06	0.57	0.57		0.57		0.01	
10:09	1	508.80	0.51	0.51		0.50		0.01	average
10:19	1	510.11	0.51	0.51		0.50		0.01	0.01
10:28	1	506.23	0.51	0.51		0.50		0.01	
10:38	1	532.53	0.53	0.53		0.52		0.03	
10:48	1	506.70	0.51	0.51		0.50		0.01	
10:57	1	516.90	0.52	0.52		0.51		0.00	
11:07	1	469.63	0.47	0.47		0.46		0.01	
11:18	1	482.64	0.48	0.48		0.47		0.01	
11:28	1	495.75	0.50	0.50		0.49		0.01	
8:46	2	1025.11	1.03		1.03		0.97		
8:56	2	1003.73	1.00		1.00		0.95	average	
9:05	2	979.53	0.98		0.98		0.92	0.06	
9:15	2	951.07	0.95		0.95		0.90		
9:24	2	929.36	0.93		0.93		0.87		
9:34	2	796.72	0.80		0.80		0.74		
9:45	2	783.85	0.78		0.78		0.73		
9:55	2	758.35	0.76		0.76		0.70		
10:05	2	689.83	0.69		0.69		0.63		
10:14	2	694.00	0.69		0.69		0.64		
10:24	2	685.85	0.69		0.69		0.63		
10:33	2	718.15	0.72		0.72		0.66		
10:43	2	731.72	0.73		0.73		0.68		
10:52	2	714.87	0.71		0.71		0.66		
11:02	2	676.31	0.68		0.68		0.62		
11:12	2	676.35	0.68		0.68		0.62		
11:23	2	659.55	0.66		0.66		0.60		
11:45	2	647.36	0.65		0.65		0.59		

avg BS Elem Hg		std BS Elem Hg	
[illegible]	ug / m3	0.10	ug / m3
avg BS Tot Hg		std BS Tot Hg	
[illegible]	ug / m3	[illegible]	ug / m3

[redacted]

Outlet Run 2

Date/Time	Chan	Result	loading	Elem Hg	Total Hg	BS Elem Hg	BS Total Hg	Total Blanks	Elem Blanks
11:59	1	443.14	0.44	0.44		0.44		0.13	0.03
12:09	1	386.93	0.39	0.39		0.38		0.12	0.02
12:18	1	438.98	0.44	0.44		0.43		0.12	0.01
12:28	1	464.95	0.46	0.46		0.46		0.13	0.01
12:37	1	327.59	0.33	0.33		0.32		0.13	0.01
12:47	1	439.59	0.44	0.44		0.43		0.13	0.01
12:57	1	452.46	0.45	0.45		0.44		0.11	0.00
13:08	1	426.81	0.43	0.43		0.42		0.02	-0.04
13:18	1	448.15	0.45	0.45		0.44		0.01	
13:27	1	310.55	0.31	0.31		0.30		0.01	average
13:37	1	375.00	0.37	0.37		0.37		0.01	0.01
13:46	1	409.45	0.41	0.41		0.40		0.01	
13:56	1	388.48	0.39	0.39		0.38		0.03	
14:05	1	354.08	0.35	0.35		0.35		0.01	
14:15	1	341.35	0.34	0.34		0.33		0.00	
14:25	1	427.23	0.43	0.43		0.42		0.01	
14:34	1	444.27	0.44	0.44		0.44		0.01	
14:44	1	445.01	0.45	0.45		0.44		0.01	
14:53	1	299.51	0.30	0.30		0.29			
15:03	1	354.22	0.35	0.35		0.35		average	
15:12	1	390.30	0.39	0.39		0.38		0.06	
15:22	1	421.33	0.42	0.42		0.41			
15:32	1	413.10	0.41	0.41		0.41			
15:41	1	404.81	0.40	0.40		0.40			
15:51	1	422.08	0.42	0.42		0.41			
16:00	1	430.93	0.43	0.43		0.42			
16:12	1	482.74	0.48	0.48		0.48			
16:21	1	491.30	0.49	0.49		0.48			
12:04	2	588.37	0.59		0.59		0.53		
12:14	2	585.70	0.59		0.59		0.53		
12:23	2	667.65	0.67		0.67		0.61		
12:33	2	616.12	0.62		0.62		0.56		
12:42	2	603.16	0.60		0.60		0.55		
12:52	2	637.65	0.64		0.64		0.58		
13:01	2	629.04	0.63		0.63		0.57		
13:13	2	624.73	0.62		0.62		0.57		
13:22	2	633.39	0.63		0.63		0.58		
13:32	2	409.45	0.41		0.41		0.35		
13:42	2	551.63	0.55		0.55		0.50		
13:51	2	611.86	0.61		0.61		0.56		
14:01	2	581.86	0.58		0.58		0.53		
14:10	2	569.41	0.57		0.57		0.51		
14:20	2	599.41	0.60		0.60		0.54		
14:29	2	612.61	0.61		0.61		0.56		
14:39	2	599.65	0.60		0.60		0.54		
14:49	2	596.70	0.60		0.60		0.54		
14:58	2	437.39	0.44		0.44		0.38		
15:08	2	515.50	0.52		0.52		0.46		
15:17	2	555.28	0.56		0.56		0.50		
15:27	2	559.72	0.56		0.56		0.50		
15:36	2	564.22	0.56		0.56		0.51		
15:46	2	594.54	0.59		0.59		0.54		
15:56	2	564.45	0.56		0.56		0.51		
16:05	2	603.16	0.60		0.60		0.55		
16:17	2	659.18	0.66		0.66		0.60		

avg BS Elem Hg		std BS Elem Hg	
0.40	ug/m3	[illegible]	ug/m3
avg BS Tot Hg		std BS Tot Hg	
[illegible]	ug/m3	[illegible]	ug/m3

[redacted]

16:26	2	654.92	0.65	0.65	0.60

Outlet Run 3

Date/Time	Chan	Result	loading	Elem Hg	Total Hg	BS Elem Hg	BS Total Hg	Total Blanks	Elem Blanks
16:50	1	456.85	0.46	0.46		0.45		0.13	0.03
17:00	1	495.61	0.50	0.50		0.49		0.12	0.02
17:09	1	482.83	0.48	0.48		0.48		0.12	0.01
17:19	1	465.65	0.47	0.47		0.46		0.13	0.01
17:28	1	500.43	0.50	0.50		0.49		0.13	0.01
17:38	1	495.75	0.50	0.50		0.49		0.13	0.01
17:47	1	470.05	0.47	0.47		0.46		0.11	0.00
17:57	1	474.64	0.47	0.47		0.47		0.02	-0.04
18:07	1	462.05	0.46	0.46		0.45		0.01	
18:16	1	343.22	0.34	0.34		0.34		0.01	average
18:26	1	441.27	0.44	0.44		0.43		0.01	0.01
18:35	1	432.85	0.43	0.43		0.43		0.01	
18:45	1	446.28	0.45	0.45		0.44		0.03	
18:54	1	437.20	0.44	0.44		0.43		0.01	
19:04	1	442.72	0.44	0.44		0.43		0.00	
19:14	1	441.36	0.44	0.44		0.43		0.01	
19:23	1	450.44	0.45	0.45		0.44		0.01	
19:33	1	463.03	0.46	0.46		0.46		0.01	
19:42	1	462.66	0.46	0.46		0.45			
19:52	1	496.59	0.50	0.50		0.49		average	
20:01	1	458.45	0.46	0.46		0.45		0.06	
20:11	1	454.70	0.45	0.45		0.45			
20:21	1	406.59	0.41	0.41		0.40			
20:30	1	439.87	0.44	0.44		0.43			
20:40	1	445.95	0.45	0.45		0.44			
20:49	1	453.06	0.45	0.45		0.45			
21:01	1	491.63	0.49	0.49		0.48			
21:10	1	495.61	0.50	0.50		0.49			
16:55	2	633.39	0.63		0.63		0.58		
17:04	2	663.53	0.66		0.66		0.61		
17:14	2	586.07	0.59		0.59		0.53		
17:24	2	620.80	0.62		0.62		0.57		
17:33	2	659.36	0.66		0.66		0.60		
17:43	2	642.00	0.64		0.64		0.59		
17:52	2	638.02	0.64		0.64		0.58		
18:02	2	625.62	0.63		0.63		0.57		
18:11	2	467.06	0.47		0.47		0.41		
18:21	2	587.52	0.59		0.59		0.53		
18:30	2	647.85	0.65		0.65		0.59		
18:40	2	648.93	0.65		0.65		0.59		
18:50	2	649.02	0.65		0.65		0.59		
18:59	2	657.68	0.66		0.66		0.60		
19:09	2	658.57	0.66		0.66		0.60		
19:18	2	662.22	0.66		0.66		0.61		
19:28	2	677.85	0.68		0.68		0.62		
19:37	2	643.26	0.64		0.64		0.59		
19:47	2	674.95	0.67		0.67		0.62		
19:57	2	700.13	0.70		0.70		0.64		
20:06	2	648.22	0.65		0.65		0.59		
20:16	2	738.22	0.74		0.74		0.68		
20:25	2	643.12	0.64		0.64		0.59		
20:35	2	669.10	0.67		0.67		0.61		
20:44	2	674.01	0.67		0.67		0.62		
20:54	2	689.88	0.69		0.69		0.63		
21:05	2	719.55	0.72		0.72		0.66		

avg BS Elem Hg		std BS Elem Hg	
[illegible]	ug / m3	[illegible]	ug / m3
avg BS Total Hg		std BS Total Hg	
[illegible]	ug / m3	[illegible]	ug / m3

[redacted]